Chapter 12: Benefit Overview

INTRODUCTION

Part III of the EEBA assesses the benefits to society from the reduced effluent discharges that will result from the MP&M industry regulations. EPA expects that benefits will accrue to society in several broad categories, including reduced health risks, enhanced environmental quality, and increased productivity in economic activities that are adversely affected by MP&M industry discharges.

This chapter provides a discussion of the ***pollutants of concern (POCs)***, their effect on human health, their environmental effects, a framework for understanding the benefits likely to be achieved by the MP&M regulation, and a qualitative discussion of those benefits. The following chapters quantify and estimate the economic value of these benefit categories. Appendices I and H provide further information on environmental effects of MP&M pollutants and water quality models used to assess these effects.

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EPA estimated national benefits expected to accrue from the regulation on the basis of sample facility data. The Agency extrapolated findings from the sample facility analyses to the national level using two alternative extrapolation methods: (1) traditional extrapolation and (2) post-stratification extrapolation. The traditional extrapolation approach relies on sample facility weights that were developed based on information about the economic and technical characteristics of the regulated community. This extrapolation approach does not incorporate information that could significantly affect the occurrence and distribution of regulatory benefits, such as characteristics of the receiving water body and the size of the population that may benefit from reduced pollutant discharges. EPA recognizes that using a traditional extrapolation method to estimate national level benefits may lead to a large degree of uncertainty in benefits estimates. Thus, EPA also used an alternative set of sampling weights, based on a post-sampling stratification method, to calculate alternative national estimates of benefits. EPA adjusted the original sample weights using two variables that are likely to affect the occurrence and size of benefits associated with reduced discharges from sample MP&M facilities: receiving water body type and size, and the size of the population residing in the vicinity of the sample facility. The following chapters present two sets of estimates of benefits expected to accrue from the MP&M regulation based on both traditional and post-stratification extrapolation approaches. Appendix G of this report provides detailed information on extrapolation methods.

In addition, the Agency used the Ohio case study results to develop a third estimate of the monetary value of national benefits.[1] EPA extrapolated the Ohio case study results to the national level based on three key factors that affect the occurrence and magnitude of benefits: (1) the estimated change in the MP&M pollutant loadings, (2) the level of recreational activities on the reaches affected by MP&M discharges, and (3) state level income. The Agency recognizes that this method is not rigorous for extrapolation to the national level. Therefore, EPA used this method only as a sensitivity analysis (see Appendix G of this report for detail).

EPA notes that effluent limitations guidelines for the MP&M industry are technology-based. EPA is not required to demonstrate environmental benefits of its technology-based rules. It is well established that EPA is not required to consider receiving water quality in setting technology-based effluent limitations guidelines and standards. Weyerhaeuser v. Costle, 590 F. 2nd 1011, 1043 (D.C. Cir. 1978) ("The Senate Committee declared that '[t]he use of any river, lake, stream or ocean as a waste treatment system is unacceptable' regardless of the measurable impact of the waste on the body of water in question. Legislative History at 1425 (Senate Report). The Conference Report states that the Act 'specifically bans pollution dilution as

[1] See Chapter 21 for a detailed discussion the Ohio case study.

an alternative to treatment.' " Id. at 284). In establishing effluent limitations and standards, EPA considers benefits as one of the factors that the Agency evaluates.

12.1 MP&M POLLUTANTS

EPA defines three general categories of pollutants: priority or toxic pollutants; nonconventional pollutants; and conventional pollutants. ***Priority pollutants (PPs)*** are defined as any of 126 named pollutants.[2] Conventional pollutants include ***biological oxygen demand (BOD)***, ***total suspended solids (TSS)***, ***oil and grease (O&G)***, ***pH***, and anything else the Administrator defines as a conventional pollutant. Nonconventionals are a catch-all category that includes everything that is not in the two previously described categories. The naming system is somewhat confusing in that some nonconventional pollutants may be as "toxic" as, or more "toxic" than some of the PPs.

MP&M effluents contain a variety of priority, nonconventional, and conventional pollutants. The release of these pollutants to our nation's surface water degrades aquatic environments, alters aquatic habitats, and affects the diversity and abundance of aquatic life. It also increases the health risks to humans who ingest contaminated surface waters or eat contaminated fish and shellfish (U.S. EPA, 1997). A number of the pollutants commonly found in MP&M effluents also inhibit biological wastewater treatment systems or accumulate in sewage sludge or sediment.

Metals are a particular concern because of their prevalence in MP&M effluents. Metals are inorganic compounds, generally non-volatile (with the notable exception of mercury), and cannot be broken down by biodegradation processes. Metals can accumulate in biological tissues, sequester into sewage sludge in ***publicly-owned treatment works (POTWs)***, and contaminate soils and sediments when released to the environment. Sediments contaminated with metals become resuspended by dredging, boat propellers, water currents or wave action, and storm events, releasing metals back into the water column. Metals can also become biologically available and enter terrestrial food chains once the sludge is applied on land. Sludges with high concentrations of metals are therefore unsuitable for land application. Some metals are quite toxic even when present at relatively low levels.

Some of the inorganic POCs found in MP&M effluents are also natural constituents of water, including potassium, calcium, magnesium, iron, chlorine, fluoride, sulfate, phosphates, silica, and a number of trace metals such as copper and zinc.

Human and ecological exposure and risk from environmental releases of MP&M pollutants depend on chemical-specific properties, the mechanism and medium of release, and site-specific environmental conditions. Chemical-specific properties include toxicological effects on living organisms, ***hydrophobicity/lipophilicity***, reactivity and persisistence. These properties are described in sections 12.1.1 through 12.1.4.

12.1.1 Characteristics of MP&M Pollutants

EPA sampled MP&M facilities nationwide to assess the concentrations of pollutants in MP&M effluents. The Agency collected samples of raw wastewater from MP&M facilities and applied standard water analysis protocols to identify and quantify the pollutant levels in each sample. EPA used these analytical data, along with selection criteria, to identify 132 contaminants of potential concern.[3]

EPA then evaluated the potential environmental fate and transport of these pollutants and their toxicity to humans and aquatic receptors. Fate of the MP&M pollutants was estimated based on the propensity of those pollutants to volatilize, adsorb onto sediments, bioconcentrate, and biodegrade. Table I.1 in Appendix I lists MP&M pollutants and provides data on human health concerns, and fate and effects.

EPA used various data sources to evaluate pollutant-specific fate and toxicity. To evaluate potential human health effects, the Agency relied on ***reference doses (RfDs)*** and ***cancer potency slope factors (SFs)***, ***human health-based water***

[2] The Agency originally had 129 PPs, but 3 have been dropped from the list bringing the number of PPs to 126.

[3] EPA originally identified 150 MP&M POCs. Of these 150 POCs, the Agency estimated loadings for 132 pollutants for the phase 2 proposal and NODA. The benefits analysis presented in this chapter and the following chapters was based on 132 pollutants for which loadings are available. The final regulation covers only the Oily Wastes subcategory and benefit reductions were estimated for 122 pollutants.

quality criteria (WQC), ***maximum contaminant levels (MCLs)*** for drinking water protection and other drinking water related criteria, and ***hazardous air pollutant (HAP)*** and PP lists. Appendix I.1.2 provides short descriptions and definitions for each of these measures of human health effects.

To evaluate potential fate and effects in aquatic environments, the Agency relied on measures of ***acute*** and ***chronic toxicity*** to aquatic species, bioconcentration factors for aquatic species, ***Henry's Law constants*** (to estimate volatility), ***adsorption coefficients (Koc)*** (to estimate association with bottom sediments), and ***biodegradation half-lives*** (to estimate the removal of chemicals via ***microbial metabolism***).

The data sources used in the assessment include EPA ***ambient water quality criteria (AWQC)*** documents and updates, EPA's ***ASsessment Tools for the Evaluation of Risk (ASTER)***, the ***AQUatic Information REtrieval System (AQUIRE)***, and the ***Environmental Research Laboratory-Duluth fathead minnow database***, EPA's ***Integrated Risk Information System (IRIS)***, EPA's ***Health Effects Assessment Summary Tables (HEAST)***, EPA's 1991 and 1993 ***Superfund Chemical Data Matrix (SCDM)***, Syracuse Research Corporation's ***CHEMFATE*** and ***BIODEG*** databases, EPA and other government reports, scientific literature, and other primary and secondary data sources.

To ensure that the assessment is as comprehensive as possible, EPA also obtained data on chemicals for which physical-chemical properties and/or toxicity data were not available from the sources listed above. To the extent possible, EPA estimated values for the chemicals using the ***quantitative structure-activity relationship (QSAR)*** model incorporated in ASTER, and for some physical-chemical properties, used published linear regression correlation equations.

12.1.2 Effects of MP&M Pollutants on Human Health

Individuals are potentially exposed to MP&M pollutants released to the aquatic environment via consumption of contaminated fish. Populations served by drinking water utilities located downstream of effluent discharges from MP&M facilities are also exposed to MP&M pollutants via contaminated drinking water. Many of these pollutants may increase risks to human health.

Based on the available human health toxicity data for the 132 POCs presented in Table I.1 (Appendix I), EPA found that:[4]

- 76 pollutants are human ***systemic toxicants***;
- 13 pollutants with published SFs are classified as known, probable, or possible human carcinogens when ingested via drinking water or food. Lead is also classified as a possible human carcinogen in IRIS but EPA has not developed a SF for it (U.S. EPA, 1998/99d);
- 36 pollutants have drinking water criteria (27 with enforceable health-based MCLs, 7 with ***secondary MCLs*** for taste or aesthetics, and 2 with action levels for treatment);
- 35 pollutants are designated as HAPs in wastewater;
- 43 pollutants are identified as PPs; and
- 76 pollutants have human health-based water quality criteria (WQC) to protect against the ingestion of water and organisms or organisms only (see Chapter 13, Table 13.3).

The carcinogens identified by EPA in MP&M effluent samples include known (A), probable (B1 and B2) and possible (C) human carcinogens. These pollutants are associated with the development of cancers in the spleen, liver, kidney, lung, bladder, and skin, among others. These pollutants and target organs are shown in Table 12.1.

[4] Facilities in the Oily Wastes subcategory discharge: 75 of the 76 systemic toxicants; all 13 human carcinogens; all 36 pollutants with drinking water criteria; all 35 pollutants designated as HAPs; 41 of the 43 priority pollutants; and 75 of the 76 pollutants that have human health-based water quality criteria. Of the 132 POCs evaluated, facilities in the Oily Wastes subcategory do not discharge the following 10 pollutants: amenable cyanide, boron, cadmium, cyanide, phosphate, sodium, sulfide, total dissolved solids, weak-acid dissociable cyanide, and ziram/cymate.

Table 12.1: Human Carcinogens Evaluated, Weight-of-Evidence Classifications, and Target Organs

CAS Number	Carcinogen	Weight-of-Evidence Classification	Target Organs
62533	Aniline	B2	Spleen
7440382	Arsenic	A	Liver, kidneys, lungs, bladder, skin
117817	Bis(2-ethylhexyl) phthalate	B2	Liver
75003	Chloroethane [a]		
75092	Dichloromethane	B2	Liver, lungs
75354	Dichloroethene, 1,1-	C	Inconclusive [b]
123911	Dioxane, 1,4-	B2	Liver, nasal cavity, gall bladder
78591	Isophorone	C	Preputial gland
62759	Nitrosodimethylamine, N-	B2	Liver, lungs, skin, seminal vesicle, lymphatic/hematopoetic system
86306	Nitrosodiphenylamine, N-	B2	Bladder tumors, reticulum cell sarcomas
127184	Tetrachloroethene	B2	Liver
79016	Trichloroethene [a]		
67663	Trichloromethane	B2	Kidneys

A = Human Carcinogen
B1 = Probable Human Carcinogen (limited human data)
B2 = Probable Human Carcinogen (animal data only)
C = Possible Human Carcinogen
[a] Pollutant has been withdrawn from the IRIS database for additional study.
[b] There is equivocal evidence for the oral route of exposure. This chemical is likely a systemic carcinogen via inhalation. Target organs include: kidney, pancreas, skin, mammary gland, and blood forming elements (lymphoma and leukemia).

Source: U.S. Environmental Protection Agency verified (IRIS) or provisional (HEAST) (U.S. EPA (1998/99d), U.S. EPA (1997)).

Non-carcinogenic hazards associated with pollutants in MP&M effluent include systemic effects (e.g., impairment or loss of neurological, respiratory, reproductive, circulatory, or immunological functions), organ-specific toxicity (e.g., kidney, small intestines, blood, testes, liver, stomach, thyroid), fetal effects (e.g., increased fetal mortality, decreased birth weight), other effects (e.g., lethargy, cataracts, weight loss, hyperactivity), and mortality. These effects are listed by pollutant in Table 12.2.

Table 12.2: MP&M Pollutants Exhibiting Systemic and Other Non-Cancer Human Health Effects[a]

CAS Number	Toxicant	RfD Target Organ and Effects
83329	Acenaphthene	Liver, hepatotoxicity
67641	Acetone	Increased liver and kidney weights, nephrotoxicity
98862	Acetophenone	General toxicity
107028	Acrolein	Cardiovascular toxicity[c]
7429905	Aluminum	Renal failure, intestinal contraction interference, adverse neurological effects[d]
120127	Anthracene	General toxicity
7440360	Antimony	Longevity, blood glucose, cholesterol
7440382	Arsenic	Hyperpigmentation, keratosis and possible vascular complications
7440393	Barium	Increased kidney weight
65850	Benzoic acid	General toxicity
100516	Benzyl alcohol	Forestomach, epithelial hyperplasia
7440417	Beryllium	Small intestinal lesions
92524	Biphenyl	Kidney damage
117817	Bis(2-ethylhexyl) phthalate	Increased relative liver weight
7440428	Boron	Testicular atrophy, spermatogenic arrest
85687	Butyl benzyl phthalate	Significantly increased liver-to-body and liver-to-brain weight
7440439	Cadmium	Significant proteinuria (protein in urine)
75150	Carbon disulfide	Fetal toxicity, malformations
108907	Chlorobenzene	Histopathologic changes in liver
75003	Chloroethane	General toxicity
7440473	Chromium	Renal tubular necrosis (kidney tissue decay)[d]
18540299	Chromium-hexavalent	Reduced water consumption
7440484	Cobalt	Heart effects[d]
7440508	Copper	Gastrointestinal effects, liver necrosis[d]
95487	Cresol, o-	Decreased body weight and neurotoxicity
106445	Cresol, p-	Central nervous system hypoactivity and respiratory system distress
57125	Cyanide	Weight loss, thyroid effects and myelin degeneration
75354	Dichloroethene, 1,1-	Toxic effects on kidneys, spleen, lungs[d]; hepatic lesions
75092	Dichloromethane	Liver toxicity
68122	Dimethylformamide, N,N-	Liver and gastrointestinal system effects
105679	Dimethylphenol, 2,4-	Clinical signs (lethargy, prostration, and ataxia) and hematological changes
84742	Di-n-butyl phthalate	Increased mortality
51285	Dinitrophenol, 2,4-	Cataract formation
606202	Dinitrotoluene, 2,6-	Mortality, central nervous system neurotoxicity, blood heinz bodies and methemoglobinemia, bile duct hyperplasia, kidney histopathology
117840	Di-n-octyl phthalate	Kidney and liver increased weights, increased liver enzymes
122394	Diphenylamine	Decreased body weight, and increased liver and kidney weights
100414	Ethylbenzene	Liver and kidney toxicity
206440	Fluoranthene	Nephropathy, increased liver weights, hematological alterations, clinical effects
86737	Fluorene	Decreased red blood cell count, packed cell volume and hemoglobin
16984488	Fluoride	Objectionable dental fluorosis (soft, mottled teeth)
591786	Hexanone, 2-	Hepatotoxicity and nephrotoxicity[c]

Table 12.2: MP&M Pollutants Exhibiting Systemic and Other Non-Cancer Human Health Effects[a]

CAS Number	Toxicant	RfD Target Organ and Effects
7439896	Iron	Liver pathology, diabetes mellitus, endocrine disturbance, and cardiovascular effects[c]
78831	Isobutyl alcohol	Hypoactivity and ataxia
78591	Isophorone	Kidney pathology
7439965	Manganese	Central nervous system effects
78933	Methyl ethyl ketone	Decreased fetal birth weight
108101	Methyl isobutyl ketone	Lethargy, increased liver and kidney weights and urinary protein
80626	Methyl methacrylate	Increased kidney to body weight ratio
91576	Methylnaphthalene, 2-	
7439987	Molybdenum	Increased uric acid
91203	Naphthalene	Decreased body weight
7440020	Nickel	Decreased body and organ weights
100027	Nitrophenol, 4-	
59507	Parachlorometacresol	
108952	Phenol	Reduced fetal body weight
129000	Pyrene	Kidney effects (renal tubular pathology, decreased kidney weights)
110861	Pyridine	Increased liver weight
7782492	Selenium	Clinical selenosis (hair or nail loss)
7440224	Silver	Argyria (skin discoloration)
100425	Styrene	Red blood cell and liver effects
127184	Tetrachloroethene	Liver toxicity, weight gain
7440280	Thallium	Liver toxicity, gastroenteritis, degeneration of peripheral and central nervous system[c]
7440315	Tin	Kidney and liver lesions
7440326	Titanium	Considered to be physiologically inert[c]
108883	Toluene	Changes in liver and kidney weights
79016	Trichloroethene	Bone marrow, central nervous system, liver, kidneys[4]
75694	Trichlorofluoromethane	Histopathology and mortality
67663	Trichloromethane	Fatty cyst formation in liver
7440622	Vanadium	Kidney and central nervous system effects[b]
108383	Xylene, m-	Central nervous system hyperactivity, decreased body weight
179601231	Xylene, m- & p- (c)	
95476	Xylene, o-	Central nervous system hyperactivity, decreased body weight
136777612	Xylene, o- & p- (c)	
7440666	Zinc	47% decrease in erythrocyte superoxide dismutase (ESOD) concentration in adult human females after 10 weeks of zinc exposure
137304	Ziram \ Cymate	

[a] Chemicals with EPA verified (IRIS) or provisional (HEAST, or other Agency document)) human health-based RfDs, referred to as "systemic toxicants" (U.S. EPA (1998/99d), U.S. EPA (1997)).

[b] RfD based on a no-observed-adverse-effect level (NOAEL). Health effects summarized from Amdur, M.O., Doul, J., and Klaassen, C.D., eds. *Cassarett and Doul's Toxicology*, 4th edition, 1991.

[c] Target organ and effects summarized from Amdur, M.O., Doul, J., and Klaassen, C.D., eds. *Cassarett and Doul's Toxicology*, 5th edition, 1996.

[d] Target organ and effects summarized from Wexler, P., ed. *Encyclopedia of Toxicology*, Volumes 1-3, 1998.

Source: U.S. EPA analysis.

12.1.3 Environmental Effects of MP&M Pollutants

Ecological impacts of MP&M pollutants include acute and chronic toxicity to aquatic receptors by dozens of pollutants present in MP&M effluents, ***uptake*** of certain pollutants into aquatic food webs, sub-lethal effects on metabolic and reproductive functions, habitat degradation from turbidity, eutrophication, dissolved oxygen depletion, and loss of prey organisms. Metals are of particular concern to this regulation because they (1) do not volatilize, (2) do not biodegrade, (3) can be toxic to plants, invertebrates and fish, (4) adsorb to sediments and (5) bioconcentrate in biological tissues.

EPA obtained the environmental fate and toxicity information for the 132 MP&M POCs. Table I.1 in Appendix I shows the environmental fate and toxicity of each MP&M pollutant.[5] EPA found that:

- 56 pollutants are not volatile or are only slightly volatile (all metals were assumed to be non-volatile except for mercury);
- 57 pollutants have moderate to high adsorption potentials (all metals were assumed to have high adsorption potential except for nickel);
- 42 pollutants have moderate to high bioconcentration factors;
- 62 pollutants biodegrade slowly or are resistant to biodegradation altogether (all metals were assumed to be resistant to biodegradation);
- For freshwater environments, 32 pollutants have acute toxicities to aquatic life that range from moderate to high, and 33 pollutants have chronic toxicities that range from moderate to high;
- For saltwater environments, 20 pollutants have acute toxicities to aquatic life that range from moderate to high, and 23 pollutants have chronic toxicities that range from moderate to high.

The available information shows that dozens of the MP&M POCs have the potential to pose significant hazards to the aquatic environment when released to receiving waters. A number of pollutants are of particular concern because of their combined toxicity and fate. These include several polyaromatic hydrocarbons (acenaphthene, anthracene, 3,6-dimethyl-phenanthrene, fluoranthene, phenanthrene, and pyrene), several metals (aluminum, cadmium, copper, mercury, and selenium) and several phthalates (di-n-octyl phthalate, butyl benzyl phthalate, and di-n-butyl phthalate). Other pollutants are of concern chiefly because of their toxicity (arsenic, cyanide, chromium, lead, nickel, silver, and zinc) or their fate (bis(2-ethylhexyl)phthalate, bromo-2-chlorobenzene, bromo-3-chlorobenzene, dibenzofuran, dibenzothiophene, diphenylamine, long-chained petroleum hydrocarbons, 1-methylfluorene, N-nitrosodiphenylamine, and several metals).

The available fate and toxicity data indicate that many MP&M pollutants tend (1) to be "toxic", (2) to not readily volatilize from the water column, (3) to adsorb to sediments, (4) to bioconcentrate in aquatic organisms, and (5) do not biodegrade. Such pollutants accumulate in sediments and reach concentrations which can impair ***benthic*** communities. Pollutants that have accumulated in sediments can be released back into the water column because sediments act as long-term sinks. The pollutants can also enter soils and reach high levels over time if present in sewage sludge that is applied to land. The tendency of these pollutants to resist biodegradation and to bioconcentrate in biological tissue also causes them to be taken up into aquatic food chains where they can affect predators or humans who consume fish and shellfish (U.S. EPA, 1998).

The toxicity data also indicate that a sizable number of the POCs in MP&M effluents have toxicities that result in lethal or sub-lethal responses in aquatic receptors, including algae, ***vascular plants***, invertebrates, fish, and amphibians. Responses include death, which may occur within a matter of hours to days, or longer-term sub-lethal responses (such as reproductive failure or growth impairment) that manifest themselves over weeks, months, or even years. The effects of toxic chemicals are not shared equally among exposed species: sensitive species are typically more affected than species that are more resistant. Hence, toxic conditions could selectively remove sensitive species from receiving waters. Such a pattern is of particular concern to ***threatened and endangered (T&E)*** species, which may already be close to extinction. Aquatic receptors are exposed to many different toxicants at the same time, which may have additive effects. The EPA assessment is based on a

[5] Note that EPA was unable to obtain fate or toxicity data for a substantial number of POCs.

chemical-by-chemical approach and therefore does not consider additive effects. This approach may understate the benefits of the rule.

EPA also did not evaluate the potential fate and effects of the four conventional pollutants (BOD, pH, O&G, TSS) and several other pollutants, including ***Total Petroleum Hydrocarbon (TPH), Total Kjeldahl Nitrogen (TKN)***, phosphorus, and ***chemical oxygen demand (COD)***, which may nonetheless adversely affect aquatic environments.[6,7]

Effluents with high levels of BOD or COD consume large amounts of dissolved oxygen in a short time, causing surface waters to become oxygen-depleted, thereby killing or excluding aquatic life (U.S. EPA, 1986). At current discharge levels, MP&M facilities discharge 1.1 million pounds of BOD per year.

Low pH (high acidity) water can be lethal to aquatic organisms; sensitive species of fish and invertebrates are eliminated from surface waters at pH's between 6.0 and 6.5 (U.S. EPA, 1999).

O&G and TPH can have lethal effects on fish by coating gill surfaces and causing asphyxia, depleting dissolved oxygen levels due to excessive BOD, and impairing stream re-aeration due to the presence of surface films. Compounds present in O&G or TPH can also be detrimental to waterfowl by affecting the buoyancy and insulating capacity of their feathers (U.S. EPA, 1998). At current discharge levels, MP&M facilities discharge 553,481 pounds per year of O&G, including 67,427 pounds a year of TPH.

TSS increases the turbidity of surface water and impairs underwater visibility and transparency, thereby inhibiting photosynthesis by diminishing the amount of sunlight that reaches algae or submerged aquatic plants. TSS also causes a general degradation of aquatic habitats by increasing the rate of sedimentation, which smothers eggs, covers aquatic plants, and affects benthic invertebrates (U.S. EPA, 1998).

High input of nitrogen in estuarine and marine systems or phosphorus in freshwater systems can increase primary productivity and result in eutrophication. Such a process overloads surface waters with algae and reduces the transparency of the water column. The excess algae sink to the bottom and decompose at the end of their life cycle. This process consumes large amounts of dissolved oxygen and can turn surface waters anoxic (U.S. EPA, 1998; U.S. EPA, 1995).

12.1.4 Effects of MP&M Pollutants on Economic Productivity

Most MP&M pollutants associated with adverse health effects are subject to drinking water criteria. Thus, MP&M discharges to surface water can increase the cost of municipal water treatment by requiring investment in chemical treatment and filtration. Public water treatment systems must comply with drinking water criteria MCLs and secondary standards. Compliance may require treatment to reduce the levels of regulated pollutants below their MCLs. Capital investment and operating and maintenance (O&M) costs associated with treatment technologies can be substantial. To the extent that the MP&M regulation reduces the concentration of MP&M pollutants in source waters to values that are below pollutant-specific drinking water criteria, public drinking water systems will accrue benefits in the form of reduced water treatment costs.

Releases of MP&M pollutants to surface waters may also increase treatment costs of irrigation water and industrial water.

Releases of large quantities or high concentrations of toxic pollutants in MP&M effluents may interfere with POTW processes (e.g., inhibiting microbial degradation), reduce the treatment efficiency or capacity of POTWs, and reduce disposal options for the sludge. In addition, toxic pollutants present in the effluent discharges may pass through a POTW and adversely affect receiving water quality, or may contaminate sludges generated during primary or secondary wastewater treatment. EPA expects no changes in the current status of POTW processes or disposal options for the sludge at POTWs receiving effluent discharges from MP&M facilities associated with the MP&M rule since all indirect dischargers have been excluded from the final option. EPA, however, analyzed changes in interferences of POTW operations and contamination of sewage sludge at

[6] TKN is defined as the total of organic and ammonia nitrogen. It is determined in the same manner as organic nitrogen, except that the ammonia is not driven off before the digestion step.

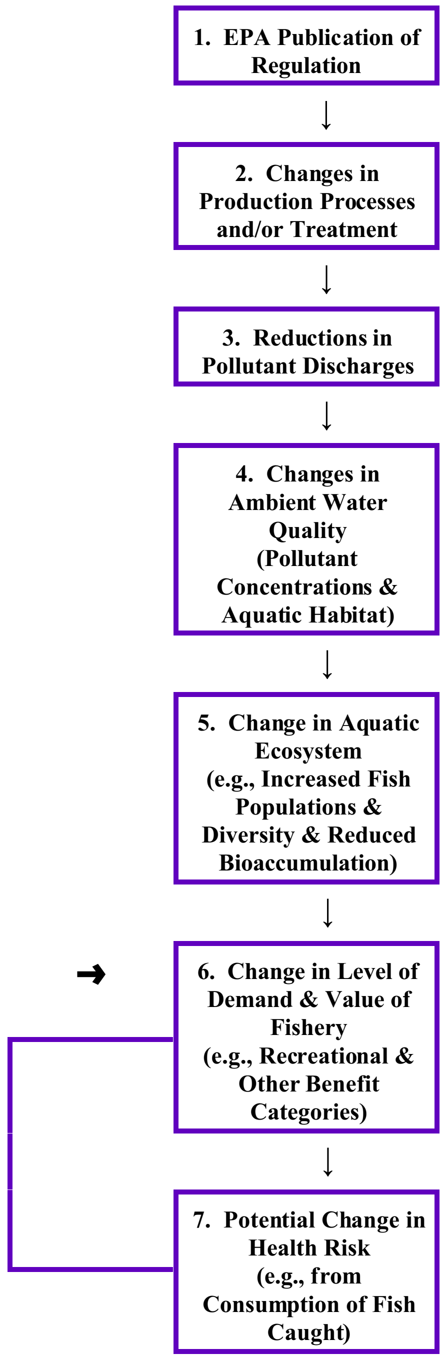
[7] EPA, however, considered environmental effects of TKN in the Ohio case study. EPA evaluated the impact of in-stream TKN concentrations on recreational value of fishing, boating, swimming, and wildlife viewing sites. For detail see Chapter 21 of this report.

POTWs receiving effluent discharges from MP&M facilities for the alternative regulatory options which include indirect dischargers.

12.2 Linking the Regulation to Beneficial Outcomes

This section describes the linkages between promulgation of a regulation and the expected benefits to society. As indicated in Figure 12.1, the benefits of the MP&M regulation occur from a chain of events. These events include: (1) Agency publication of the regulation, (2) industry changes in production processes and/or treatment systems, (3) reductions in pollutant discharges, (4) changes in water quality, (5) changes in ecosystem attributes and sewage sludge quality, (6) changes in human responses, and (7) changes in human health and ecological risk. The first two events reflect the institutional and technical aspects of the regulation. The benefit analysis begins with the third event, the changes in the pollutant content of effluent discharges.

Figure 12.1: Chain of Events in a Benefits Analysis



Source: U.S. EPA analysis.

In event four, changes in pollutant discharges translate into improvements in water and sludge quality. In event five, these improvements in turn affect in-stream and near-stream biota (e.g., increased diversity of aquatic species and size of species populations) and sludge disposal options. Finally, human effects and the related valuation of benefits occur in events six and seven. For example, improvements to recreational fisheries and enhanced enjoyment by recreational anglers is connected to improved water quality and the value of reduced risk to human health. These linkages are the basis of the benefits analysis presented in this and the following chapters.

12.3 Qualitative and Quantitative Benefits Assessment

A benefit assessment defines and quantifies the types of improvements to human health and ecological receptors that can be expected from reducing the amount of MP&M pollutants released to the environment. The following sections provide an overview of the concepts and analytic approaches involved in the benefits assessment. The first section describes the general categories of benefits expected to result from the regulation and the level of analysis undertaken for them. The following three sections review, within the broad categories of benefits likely to be achieved by the MP&M regulation, the specific benefits that are evaluated in this analysis. Finally, Section 12.3.5 summarizes methods for attaching values to some of the benefit measures. Chapters 13 through 16 present the quantitative assessment of benefits.

12.3.1 Overview of Benefit Categories

The benefits of reduced MP&M discharges may be classified in three broad categories: human health, ecological, and economic productivity benefits. Table 12.3 summarizes the different types of benefits that fall in each of these categories. Each category is comprised of a number of more narrowly defined benefit categories. EPA expects that the MP&M regulation will provide benefits to society in all of these categories. EPA was not able to bring the same depth of analysis to all of these categories, however, because of imperfect understanding of the link between discharge reductions and benefit categories, and how society values some of the benefit events. EPA was able to quantify and monetize some benefits, quantify but not monetize other benefits, and assess still other benefits only qualitatively.

In addition to the national-level benefits analysis, the Agency conducted a case study in the state of Ohio to provide in-depth analysis of the regulation's expected benefits. The Ohio case study improves on the national analysis in two ways. First, the analysis uses improved data and methods to address co-occurrence of MP&M facility benefits and other-source contributions of MP&M pollutants in the same locations. Second, the analysis of recreational benefits is based on original travel cost models of resource valuation in a random utility framework. The analysis values changes in the value of water resources for four recreational activities -- fishing, boating, swimming, and near-water recreation. Due to data limitations, only three of these four activities were valued at the national-level benefits analysis.

To provide perspective on the extent to which this regulatory impact assessment was able to comprehensively analyze the benefits, Table 12.3 summarizes the specific benefits within each of the three broad benefit categories that are expected to accrue from the MP&M regulation and the level of analysis applied to each category. As shown in Table 12.3, only a few of the relevant benefit categories can be both quantified and monetized.

Table 12.3: Level of Analysis Performed for Specific Benefit Categories

Benefit Category	Quantified and Monetized	Quantified but Not Monetized	Qualitative
Human Health Benefits			
Reduced cancer risk due to ingestion of chemically-contaminated fish and unregulated pollutants in drinking water	X		
Reduced non-cancer adverse health effects (e.g. reproductive, immunological, neurological, circulatory, or respiratory toxicity) due to ingestion of chemically-contaminated fish and unregulated pollutants in drinking water		X	
Reduced non-cancer adverse health effects from exposure to lead from consumption of chemically-contaminated fish	X		
Reduced cancer risk and non-cancer adverse health effects from exposure to unregulated pollutants in chemically-contaminated sewage sludge[a]			X
Reduced health hazards from exposure to contaminants in waters used recreationally (e.g., swimming)			X
Ecological Benefits			
Reduced risk to aquatic life		X	
Enhanced water-based recreation including fishing, boating, and near-water (wildlife viewing) activities	X		
Other enhanced water-based recreation such as swimming, waterskiing, and white water rafting			X
Increased aesthetic benefits such as enhancement of adjoining site amenities (e.g. residing, working, traveling, and owning property near the water)			X
Nonuser value (i.e., existence, option, and bequest value)	X		
Reduced contamination of sediments			X
Reduced non-point source nitrogen contamination of water if sewage sludge is used as a substitute for chemical fertilizer on agricultural land[a]			X
Satisfaction of a public preference for beneficial use of sewage sludge[a]			X
Economic Productivity Benefits			
Reduced sewage sludge disposal costs[a]	X		
Reduced management practice and record-keeping costs of sewage sludge that meets exceptional quality criteria[a]	X		
Reduced interference with POTW operations[a]		X	
Benefits to tourism industries from increased participation in water-based recreation			X
Improved commercial fisheries yields			X
Improved crop yield (the organic matter in land-applied sewage sludge increases soil's water retention)[a]			X
Avoidance of costly siting processes for more controversial sewage sludge disposal methods (e.g., incinerators) because of greater use of land application[a]			X
Reduced water treatment costs for municipal drinking water, irrigation water, and industrial process and cooling water			X

[a] These benefit categories are not applicable to the final rule since all indirect dischargers have been excluded from the selected option. EPA, however, analyzed these benefit categories for the alternative regulatory options which include indirect dischargers.

Source: U.S. EPA analysis.

Each category of benefits and the level of analysis applied to this category are discussed in greater detail below.

12.3.2 Human Health Benefits

Reduced pollutant discharges to the nation's waterways will generate human health benefits by several mechanisms. The most important and readily analyzed benefits stem from reduced risk of illness associated with the consumption of water, fish, shellfish, and other aquatic organisms that is taken from waterways affected by MP&M discharges. Human health benefits are typically analyzed by estimating the change in the expected number of adverse human health events in the exposed population resulting from a reduction in effluent discharges. While some health effects such as cancer are relatively well understood and thus may be quantified in a benefits analysis, others are less well characterized and cannot be assessed with the same rigor or at all.

EPA analyzed the following direct measures of change in risk to human health: incidence of cancer from fish and water consumption; reduced risk of non-cancer toxic effects from fish and water consumption; and lead-related health effects to children and adults. EPA was able to monetize only two of the three measures (cancer-related and lead-related health risks). Incidence of cancer was translated into an expected number of avoided mortality events and, on that basis, monetized. Lead impacts to children were evaluated in terms of potential intellectual impairment as measured by estimated changes in IQ. Changes in adverse health effects to adults from lead exposure were measured in terms of reduced risk of hypertension, non-fatal coronary heart disease, non-fatal strokes, and mortality.

EPA also quantified but did not monetize the expected reduction of pollutant concentrations in excess of health-based AWQC limits. This benefit measure was obtained by comparing in-waterway pollutant concentrations to toxic effect levels.

In concept, the value of these health effects to society is the monetary value that society is willing to pay to avoid the health effects, or the amount that society would need to be compensated to accept increases in the number of adverse health events. ***"Willingness-to-pay" (WTP)*** values are generally considered to provide a fairly comprehensive measure of society's valuation of the human and financial costs of illness associated with the costs of health care, losses in income, and pain and suffering of affected individuals and of their family and friends.

In some cases, available economic research provides little empirical data for society's WTP to avoid certain health effects. One component of the cost of an illness estimates the direct medical costs of treating a health condition (e.g., hypertension), and can be used to value changes in health risk from reduced exposure to toxic pollutants such as lead. These estimates represent only one component of society's WTP to avoid adverse health effects and therefore produce a partial measure of the value of reduced exposure to MP&M pollutants. Employed alone, these monetized effects will significantly underestimate society's WTP.

12.3.3 Ecological Benefits

EPA expects that the ecological benefits from the regulation will include protection of fresh- and saltwater plants, invertebrates, fish, and amphibians, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to MP&M pollutants. The regulation will reduce the presence and discharge of various pollutants and will enhance or protect aquatic ecosystems currently under stress. The drop in pollutant loading is expected to reestablish productive ecosystems in damaged waterways and to protect resident species, including T&E species. EPA also expects that the regulation will enhance the general health of fish and invertebrate populations, increase their propagation to waters currently impaired, and expand fisheries for both commercial and recreational purposes. Improvements in water quality will also favor increased recreational activities such as swimming, boating, fishing, and water skiing. Finally, the Agency expects that the regulation will augment nonuse values (e.g., option, existence, and bequest values) of the affected water resources.

It is frequently difficult to quantify and attach economic values to ecological benefits. The difficulty results from imperfect understanding of the relationship between changes in effluent discharges and the specific ecological changes, lack of water quality monitoring data for most locations, and time lags between water quality changes and changes in species population and composition. In addition, it is difficult to attach monetary values to these ecological changes because they often do not occur in markets in which prices or costs are readily observed. As such, ecological benefits may be loosely classified as nonmarket benefits. This classification can be further divided into nonmarket *use* benefits and nonmarket *nonuse* benefits.

Nonmarket use benefits stem from improvements in ecosystems and habitats, which in turn lead to enhanced human use and enjoyment of these areas. For example, reduced discharges may lead to increased recreational use and enjoyment of affected waterways in such activities as fishing, swimming, boating, hunting or near-water activities such as bird watching. In some cases, it may be possible to quantify and attach partial economic values to ecological benefits using market values (e.g., an increase in tourism or boat rentals associated with improved recreational fishing opportunities); in this case, these benefit events might better be classified as economic productivity related events, which are discussed below. Economic markets, however, do not provide enough information to fully capture the value of these benefits. Such markets capture only related expenditures made by recreationists (e.g., food and lodging) and do not capture the value placed on the experience itself. A variety of nonmarket valuation techniques can be used to capture the value placed on the resource in question. These techniques include hedonic valuation (wage-risk studies) and ***travel cost methods (TCM)***, stated preferences methods (i.e., ***contingent valuation (CV)***, ***contingent rating (CR)***, ***contingent activity (CA)***, benefits transfer, and averting behavior models.

Nonmarket nonuse benefits are not associated with current use of the affected ecosystem or habitat, but rather arise from (1) the *realization* of the improvement in the affected ecosystem or habitat resulting from reduced effluent discharges and (2) the value that individuals place on the *potential for use* sometime in the future. Nonmarket nonuse benefits may also be manifested by other valuation mechanisms, such as cultural valuation, philanthropy, and bequest valuation. It is often extremely difficult to quantify the relationship between changes in discharges and the improvements in societal well-being associated with such valuation mechanisms. That these valuation mechanisms exist, however, is indisputable, as evidenced, for example, by society's willingness to contribute to organizations whose mission is to purchase and preserve lands or habitats to avert development.

12.3.4 Economic Productivity Benefits

Reduced pollutant discharges may also benefit economic productivity. First, economic productivity benefits may accrue from reduced treatment costs of drinking water, irrigation water, and industrial use water. Reduced pollutant concentrations in public water systems source water to levels at or below MCLs or secondary standards could reduce ongoing treatment costs and avoid the need to invest in treatment technologies in the future. Reduced pollutant discharges may also reduce sediment dredging costs. Contaminated sediments may contribute substantially to contamination of aquatic biota and to human exposure of human health toxicants. Controlling point source discharges of toxic pollutants can prevent sediment contamination and eliminate the need for future remediation (i.e., dredging) of contaminated sediments.

Other economic productivity gains may result from improved tourism opportunities in areas affected by MP&M discharges. Improved aquatic species survival may contribute to increased commercial fishing yield. When such economic productivity effects can be identified and quantified, they are generally straightforward to value because they involve market commodities for which prices or unit costs are readily available.

Economic productivity gains may also occur through reduced costs to public sewage systems (POTWs) for managing and disposing of the sludge (i.e., biosolids) from treating effluent discharges. For example, higher quality sludge may be applied to agricultural land or otherwise beneficially used rather than being incinerated or disposed of in landfills. POTWs may also incur lower costs because of lower record keeping requirements. Under the final regulatory option, EPA expects no POTW productivity gains since all indirect dischargers have been excluded from the final regulatory option.

12.3.5 Methods for Valuing Benefit Events

Some of the benefits expected from the MP&M regulation will manifest themselves in economic markets through changes in price, cost, or quantity of market-valued activities. For benefits endpoints traded in markets, such as increased yields from commercial fisheries, benefits can be measured by market prices or market-based factor pricing. Competitive prices can be used also to measure ***avoided cost*** type of benefits. For example, reduced pollutant loadings to public water supplies may lower costs of drinking treatment. Market prices can be used also to value direct medical costs of illnesses associated with exposure to pollutants. For this analysis, EPA used medical costs associated with treating hypertension, coronary heart disease, and stroke to estimate benefits from reduced exposure to lead (see Chapter 14). The estimated values can be used as minimum measures of the benefits associated with reduced cases of these illnesses.

In other cases, benefits involve activities or sources of value that either do not involve economic markets or involve them only indirectly. Methods used to value such benefits are described briefly below:

a. Wage-risk approach.

The wage-risk approach uses regression estimates of the wage premium associated with greater risks of death on the job to estimate the amount that persons are willing to pay to avoid death. Benefit values based on this approach are used as part of the basis for valuing reduced cancer cases due to fish consumption in Chapter 13.

b. Travel cost method

The TCM uses information on costs incurred by people in traveling to a site and in using the site to estimate a demand curve for that site. The demand curve is then used to estimate the "consumer surplus" associated with the use of the site, that is, the value that consumers receive from the site over and above the costs that they incur in using it. Consumer surplus is an estimate of the net benefits of the resource to the people using that resource. For example, if the resource is a recreational fishing site, the TCM can be used to value the recreational fishing experience. The Agency used an original travel cost study to value benefits from enhanced water-based recreation in Ohio (see Part V: Chapter 21). The analysis of recreational benefits in Chapter 15 uses a meta-analysis of water-based recreation studies (including TCM studies) to derive the baseline and post-compliance values of water-based recreation activities (including fishing, boating, and wildlife viewing) and to estimate benefits to consumers of water-based recreation from improved water quality resulting from reduced MP&M dischargers.

c. Contingent valuation

In the CV method, surveys are conducted to elicit individuals' WTP for a particular good, such as a fishery, or clean water. CV is more broadly applicable than TCM. Like TCM, CV can be used to estimate the consumer surplus associated with recreational fisheries. CV can also be used to estimate less tangible values, such as how much people care about a clean environment. Values from both the CV approach and the wage-risk approach support the estimated value of avoided death that is used to monetize reduced cancer cases from consumption of contaminated fish (Chapter 13). Similarly to the TCM studies, CV studies are used in a meta-analysis to derive the baseline and post-compliance values of water-based recreation activities (including fishing, boating, and wildlife viewing) and to estimate benefits from improved opportunities for water-based recreation from reduced MP&M dischargers (Chapter 15).

d. Benefits transfer

When time and resource constraints preclude primary research, benefit assessment based on benefits transfer from existing studies is used. This approach involves extrapolating benefit findings for one analytic situation to another. The relevant study situations are defined by type of environmental resource (e.g., fishery), policy variable(s), and the characteristics of user populations. The benefits transfer approach is used to monetize several benefit categories, including changes in the incidence of cancer cases (Chapter 13) and the national-level benefits from enhanced water-based recreation (Chapter 15).

The techniques described above form the basis of the benefits methodologies described in Chapters 13,14, and 15.

GLOSSARY

acute toxicity: the ability of a substance to cause severe biological harm or death soon after a single exposure or dose. Also, any poisonous effect resulting from a single short-term exposure to a toxic substance. (See: chronic toxicity, toxicity.) (http://www.epa.gov/OCEPAterms/aterms.html)

adsorption coefficients (Koc): represents the ratio of the target chemical absorbed per unit weight of organic carbon in the soil or sediment to the concentration of that same chemical in solution at equilibrium.

ambient water quality criteria (AWQC): AWQC present scientific data and guidance of the environmental effects of pollutants which can be useful to derive regulatory requirements based on considerations of water quality impacts; these criteria are not rules and do not have regulatory impact (U.S. EPA. 1986. Quality Criteria for Water 1986. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC. EPA 440/5-86-001).

AQUatic Information REtrieval System (AQUIRE): a web-based ecotoxicity database maintained by EPA's Mid-Continent Ecology Division (MED) which summarizes ecotoxicity data retrieved from the literature. (http://www.epa.gov/med/databases/databases.html#aquire) (U.S. EPA, 1998/99b)

ASsessment Tools for the Evaluation of Risk (ASTER): an ecological risk assessment tool developed by EPA's Mid-Continent Ecology Division (MED); ASTER integrates information from the AQUIRE toxic effects database and the QSAR system (a structure activity-based expert system) to estimate ecotoxicity, chemical properties, biodegradation and environmental partitioning. (http://www.epa.gov/med/databases/aster.html) (U.S. EPA, 1998/99c)

avoided cost: costs that are likely to be incurred in the future if current conditions still prevail at the time, but which will be avoided if particular actions are taken now to change the status quo.

benthic: relating to the bottom of a body of water; living on, or near, the bottom of a water body.

BIODEG: a web-based biodegradation database developed by Syracuse Research Corporation. (http://esc.syrres.com/efdb/BIODGSUM.HTM) (Syracuse Research Corporation, 1999)

biodegradation half-lives: represents the number of days a compound takes to be degraded to half of its starting concentration under prescribed laboratory conditions.

biological oxygen demand (BOD): the amount of dissolved oxygen consumed by microorganisms as they decompose organic material in an aquatic environment.

cancer potency slope factor (SF): a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.

CHEMFATE: a web-based chemical fate database developed by Syracuse Research Corporation. (http://esc.syrres.com/efdb/Chemfate.htm) (Syracuse Research Corporation, 1999)

chemical oxygen demand (COD): a measure of the oxygen required to oxidize all compounds, both organic and inorganic, in water. (http://www.epa.gov/OCEPAterms/cterms.html)

chronic toxicity: the capacity of a substance to cause long-term poisonous health effects in humans, animals, fish, and other organisms. (http://www.epa.gov/OCEPAterms/cterms.html)

contingent activity: one of the stated preference methods (see: contingent valuation and contingent activity). Survey respondents are asked how their behavior would change in response to a proposed change in one or more attributes of an activity (e.g., cost of the activity, site accessibility, or site attractiveness). Given responses to this type of question, and given information about incremental travel costs and value of time, a revealed preference method can be used to estimate the value of change.

contingent rating: one of the stated preference methods (see: contingent valuation and contingent activity). Survey respondents are asked to rate several alternatives on an ad hoc utility scale (e.g., 1 to 10). The choice set of alternatives usually includes the environmental effect to be valued, substitutes for the effect, and a good with a monetary price to act as a threshold. Based on the respondent's rating of the environmental effect and the threshold good, and the monetary price of the threshold good, the value of the environmental effect can be determined.

contingent valuation (CV): a method used to determine a value for a particular event, where people are asked what they are willing to pay for a benefit and/or are willing to receive in compensation for tolerating a cost. Personal valuations for increases or decreases in the quantity of some good are obtained contingent upon a hypothetical market. The aim is to elicit valuations or bids that are close to what would be revealed if an actual market existed. (http://www.damagevaluation.com/glossary.htm)

Environmental Research Laboratory-Duluth fathead minnow database: a database developed by EPA's Mid-Continent Ecology Division (MED) which provides data on the acute toxicity of hundreds of industrial organic compounds to the fathead minnow. (http://www.eoa.gov/med/databases/fathead_minnow.html) (U.S. EPA, 1998/99a)

hazardous air pollutant (HAP): compounds that EPA believes may represent an unacceptable risk to human health if present in the air.

Health Effects Assessment Summary Tables (HEAST): a comprehensive listing of provisional human health risk assessment data relative to oral and inhalation routes for chemicals of interest to EPA. Unlike data in IRIS, HEAST entries have received insufficient review to be recognized as high quality, Agency-wide consensus information. (U.S. EPA. 1997. Health Effects Assessment Table; FY 1997 Update. EPA-540-R-97-036)

Henry's Law constant: a numeric value which relates the equilibrium partial pressure of a gaseous substance in the atmosphere above a liquid solution to the concentration of the same substance in the liquid solution.

human health-based water quality criteria (WQC): human health-based criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes (see ambient water quality criteria (AWQC)). (http://www.epa.gov/OCEPAterms/wterms.html).

hydrophobicity: having a strong aversion to water. (http://www.epa.gov/OCEPAterms/hterms.html)

Integrated Risk Information System (IRIS): IRIS is an electronic database with information on human health effects of various chemicals. IRIS provides consistent information on chemical substances for use in risk assessments, decision-making and regulatory activities.

lipophilicity: having a strong attraction to oils

maximum contaminant levels (MCLs): the maximum permissible level of a contaminant in water delivered to any user of a public system. MCLs are enforceable standards. (http://www.epa.gov/OCEPAterms/mterms.html)

metals: inorganic compounds, generally non-volatile, and which cannot be broken down by biodegradation processes. They are a particular concern because of their prevalence in MP&M effluents. Metals can accumulate in biological tissues, sequester into sewage sludge in POTWs, and contaminate soils and sediments when released to the environment. Some metals are quite toxic even when present at relatively low levels.

microbial metabolism: biochemical reactions occurring in living microorganisms such as bacteria, algae, diatoms, plankton, and fungi. POTWs make use of bacterial metabolism for wastewater treatment purposes. This process is inhibited by the presence of toxins such as metals and cyanide because these pollutants kill bacteria.

oil and grease (O&G): organic substances that may include hydrocarbons, fats, oils, waxes, and high-molecular fatty acids. Oil and grease may produce sludge solids that are difficult to process. (http://www.epa.gov/owmitnet/reg.htm)

pH: an expression of the intensity of the basic or acid condition of a liquid; natural waters usually have a pH between 6.5 and 8.5. (http://www.epa.gov/OCEPAterms/pterms.html)

pollutants of concern (POCs): are the 150 contaminants identified by EPA as being of potential concern for this rule and which are currently being discharged by MP&M facilities.

priority pollutant (PP): 126 individual chemicals that EPA routinely analyzes when assessing contaminated surface water, sediment, groundwater, or soil samples.

publicly-owned treatment works (POTWs): a treatment works, as defined by section 212 of the Act, that is owned by a State or municipality. This definition includes any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW Treatment Plant. (http://www.epa.gov/owm/permits/pretreat/final99.pdf)

quantitative structure-activity relationship (QSAR) model: an expert system which uses a large database of measured physicochemical properties such as melting point, vapor pressure, and water solubility to estimate the fate and effect of a specific chemical based on its molecular structure. (http://www.epa.gov/med/databases/aster.html) (U.S. EPA, 1998/99)

reference doses (RfDs): chemical concentrations expressed in mg of pollutant/kg body weight/day, that, if not exceeded, are expected to protect an exposed population, including sensitive groups such as young children or pregnant women.

secondary MCLs: human health-based drinking water criteria to assess the health hazards associated with the presence of certain toxic chemicals in drinking water. SMCLs are established for taste or aesthetic effects.

Superfund Chemical Data Matrix (SCDM): a source for factor values and benchmark values applied when evaluating potential National Priorities List (NPL) sites using the Hazard Ranking System (HRS). (http://www.epa.gov/superfund/resources/scdm/index.htm).

suspended solids: small particles of solid pollutants that float on the surface of, or are suspended in, water bodies. (http://www.epa.gov/OCEPAterms/sterms.html)

systemic toxicants: chemicals that EPA believes can cause significant non-carcinogenic health effects when present in the human body above chemical-specific toxicity thresholds.

threatened and endangered (T&E): animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (man-caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

Total Petroleum Hydrocarbon (TPH): a general measure of the amount of crude oil or petroleum product present in an environmental media (e.g., soil, water, or sediments). While it provides a measure of the overall concentration of petroleum hydrocarbons present, TPH does not distinguish between different types of petroleum hydrocarbons.

Total Kjeldahl Nitrogen (TKN): the total of organic and ammonia nitrogen. TKN is determined in the same manner as organic nitrogen, except that the ammonia is not driven off before the digestion step.

total suspended solids (TSS): a measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids." (See: suspended solids.) (http://www.epa.gov/OCEPAterms/tterms.html)

travel cost method (TCM): method to determine the value of an event by evaluating expenditures of recreators. Travel costs are used as a proxy for price in deriving demand curves for the recreation site. (http://www.damagevaluation.com/glossary.htm)

uptake: the movement of one or more chemicals into an organism via ingestion, inhalation, and/or through the skin.

vascular plants: plants that are composed of, or provided with, vessels or ducts that convey fluids. (www.infoplease.com)

willingness-to-pay (WTP): maximum amount of money one would give up to buy some good. (http://www.damagevaluation.com/glossary.htm)

ACRONYMS

AQUIRE: AQUatic Information REtrieval System
ASTER: ASsessment Tools for the Evaluation of Risk
AWQC: ambient water quality criteria
BIODEG: biodegradation
BOD: biological oxygen demand
CA: contingent activity
CHEMFATE: chemical fate
CR: contingent rating
CV: contingent valuation
COD: chemical oxygen demand
HAP: hazardous air pollutant
HEAST: Health Effects Assessment Summary Tables
IRIS: Integrated Risk Information System
Koc: adsorption coefficient
MCL: maximum contaminant level
O&G: oil and grease
POC: pollutant of concern
POTW: publicly-owned treatment work
PP: priority pollutant
QSAR: quantitative structure-activity relationship
RfD: reference dose
SCDM: Superfund Chemical Data Matrix
SF: cancer potency slope factor
T&E: threatened and endangered
TCM: travel cost method
TKN: Total Kjeldahl Nitrogen
TPH: Total Petroleum Hydrocarbon
TSS: total suspended solids
WQC: human health-based water quality criteria
WTP: willingness-to-pay

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Chapter 13: Human Health Benefits

INTRODUCTION

EPA expects that the final MP&M regulation will yield a range of human health benefits by reducing effluent discharges to ***waterways*** used for fishing or drinking water.

This chapter analyzes four categories of expected human health benefits. The first two categories involve reductions in cancer cases from two exposure pathways: consumption of contaminated fish tissue and ingestion of contaminated drinking water for the exposed population. EPA evaluated the expected annual reduction in cancer cases in the exposed population and the associated monetary value of avoiding those cancer cases.

EPA quantified, but did not monetize, two additional measures of human health-related benefits. The first is the changes in fish consumption and drinking water exposures to non-cancer causing pollutants measured against non-cancer health effect ***reference doses (RfDs)***, an indicator of non-cancer health risk. The second benefit measure is the change in occurrence of pollutant concentrations that are estimated to exceed human health-based ***ambient water quality criteria (AWQC)***.

EPA also quantified and monetized changes in health risk to adults and children from reduced exposure to lead. This analysis is presented in Chapter 14.

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The health-related measures were estimated for the baseline and for the final option for all of the benefit categories analyzed. In addition, EPA estimated health benefits for alternative options which EPA considered for the MP&M regulation. The reduction in the health-related measures (i.e., number of annual cancer cases) from baseline to the post-compliance case is the estimated benefit of the MP&M regulation. As discussed in Chapter 12, EPA estimated national benefits for the regulation based on sample facility data. The Agency extrapolated findings from the sample facility analyses to the national level using two alternative extrapolation methods: (1) traditional extrapolation and (2) post-stratification extrapolation. Appendix G provides detailed information on the extrapolation approaches used in this analysis.

EPA estimated that, for combined recreational and subsistence angler populations, the final option would lead to a marginal reduction in cancer cases. The total monetized human health benefits from reduced cancer cases from both the fish consumption and drinking water pathways are essentially negligible (i.e., $90 per year based on the traditional extrapolation and $134 per year based on the post-stratification extrapolation (2001$)).

Benefits will also be realized in the form of reductions in non-cancer human health effects (e.g., systemic effects, reproductive toxicity, and developmental toxicity) from reduced contamination of fish tissue and drinking water sources. For this analysis, EPA estimates the numbers of individuals in the exposed populations who might be expected to realize reduced risk of non-cancer health effects in the post-compliance scenario. To evaluate the potential benefits of reducing the in-stream concentrations of 76 pollutants that cause non-cancer health effects, EPA estimated target organ-specific hazard indices (HI) for drinking water and fish ingestion exposures in both the baseline and post-compliance scenarios. HI values below one are generally considered to suggest that exposures are not likely to result in appreciable risk of adverse health effects during a lifetime, and values above one are generally cause for concern, although an HI greater than one does not necessarily suggest a likelihood of adverse effects.

The results of EPA's analysis suggest that the incremental risk of non-cancer effects from pollutants discharged by MP&M facilities alone is quite low. This analysis found that HIs for the entire population associated with sample facilities is less than one in the baseline. The results of EPA's analysis of the post-compliance scenario indicate that hazard indices for individuals in the exposed population may decrease after facilities comply with the MP&M regulation. Increases in the percentage of exposed populations that would be exposed to no risk of non-cancer adverse human health effects due to the MP&M discharges occur in both the fish and drinking water analyses. Whether the incremental shifts in HIs are significant in reducing absolute risks of non-cancer adverse human health effects is uncertain and will depend on the magnitude of contaminant exposures for a given population from risk sources not accounted for in this analysis.

Finally, EPA analyzed the effect of the final regulation on occurrence of pollutant concentrations resulting from MP&M discharges that exceed human health-based AWQC. EPA estimated that, as the result of baseline MP&M pollutant discharges, in-stream concentrations exceed human health-based AWQC in 78 and 112 receiving reaches nationwide based on the traditional extrapolation and post-stratification extrapolation, respectively. EPA estimated that none of these exceedances will be eliminated under the final option.

13.1 Methodology & Data Sources

Individuals are potentially exposed to pollutants from MP&M facilities via consumption of contaminated fish tissue and drinking water. Potential human health effects include cancer and non-cancer health effects. Risks such as skin, lung, liver, kidney, and bladder cancer and leukemia are associated with exposure to 13 MP&M pollutants (see Table 13.1). Non-cancer health effects are associated with exposure to 76 MP&M pollutants. These effects include increased blood pressure, gastrointestinal effects, liver and kidney toxicity, cardiovascular and central nervous system effects, and decreased birth weight (see Table 13.2).

This section summarizes the methodology for estimating national benefits for three benefit categories:

1. reduced incidence of cancer from consumption of fish taken from waterways affected by MP&M industry discharges,

2. reduced incidence of cancer from ingestion of water taken from waterways affected by MP&M industry discharges, and

3. reduced occurrence of pollutant concentrations resulting from MP&M discharges that exceed human health-based AWQC.

This analysis does not include all possible human health benefits and does not provide a comprehensive estimate of the total human health benefits associated with the final MP&M rule. Analyses of health benefits are not possible for a significant number of the pollutants whose discharges will be reduced under the post-compliance scenario due to the lack of data on a quantitative relationship between ingestion rate and the potential health effects associated with these chemicals.

Beyond these important limitations, the methodologies used to assess the human health benefits involve significant simplifications and uncertainties. Elements of the analysis involving significant simplifications and uncertainties include the following: sample design and analysis of benefits by location of occurrence; estimation of in-waterway concentrations of MP&M pollutants; consideration of the joint effects of pollutants; consideration of background concentrations of MP&M pollutants; consideration of downstream effects; and estimation of the exposed fishing population. Section 13.3 provides more detail on limitations and uncertainties associated with the human health benefits analyses. Whether these simplifications and uncertainties, taken together, are likely to lead to an understatement or overstatement of the estimated economic values for the human health benefits that were analyzed is not known.

13.1.1 Cancer from Fish Consumption

The analysis of reduced annual occurrence of cancer in exposed populations via the fish consumption pathway involves three analytic steps:

- estimating the reduced annual risk of incurring cancer per exposed individual;

- estimating the population that would be expected to benefit from reduced contamination of fish; and

- calculating the change in the number of cancer events in the exposed population.

Each step is discussed in detail below.

a. Estimating change in individual cancer risk

The estimated incremental risk to an individual of developing cancer is based on four factors:[1]

- the quantity of carcinogenic chemicals that MP&M facilities discharge to waterways,
- the rate at which the discharged chemicals accumulate in fish tissue,
- the cancer effect of the chemicals, and
- the rate of personal consumption of contaminated fish.

For each sample MP&M facility and the waterway to which it discharges, EPA calculated the incremental cancer risk to four population classes with different fish consumption rates: children in families that participate in recreational angling, children in families that participate in subsistence angling, adults in families that participate in recreational angling, and adults in families that participate in subsistence angling. EPA calculated the incremental cancer risk values for baseline (i.e., before regulation) pollutant discharges and for post-compliance discharges based on the policy options considered in the final rule analysis. The following discussion summarizes the incremental cancer risk calculations.

EPA calculated the in-waterway pollutant concentrations for each reach receiving discharges from an MP&M facility using a simplified dilution model for all chemicals for which a quantitative relationship between ingestion rate and the annual probability of developing cancer has been estimated. A "***reach***" is a specific length of river, lake shoreline, or marine coastline, and an "***MP&M reach***" is one to which an MP&M facility discharges.[2] This analysis considered only the discharge reach and did not estimate concentrations below the initial MP&M reach. The water quality model used for calculating in-waterway pollutant concentrations accounts for the dilution characteristics of different water body types (i.e., streams, estuaries, and lakes). It does not account for other fate processes, such as chemical degradation or photolysis. The estimated pollutant concentrations reflect the average pollutant concentrations in the reach to which a facility discharges. For additional details on the calculation of waterway concentrations, see Appendix I.

The incremental cancer risk associated with each pollutant was calculated based on the estimated concentration of the pollutant in the affected waterway, the assumed uptake of the pollutant into fish flesh, the daily rate of fish ingestion, and the cancer risk factor for each pollutant. The formula for calculating the risk to an individual from consumption of a given chemical is as follows:

$$Risk = \frac{C \times CF_1 \times BCF \times CR \times EF \times ED}{BW \times LT \times CF_2} \times SF \qquad (13.1)$$

where:

Risk	=	incremental risk of incurring cancer from fish consumption (change in probability);
C	=	pollutant concentrations in surface water (µg/l);
CF_1	=	conversion factor, micrograms to milligrams (0.001 mg/µg);
BCF	=	bioconcentration factor of pollutant in fish (l/kg);
CR	=	human consumption rate of fish (kg/day);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (years);
BW	=	human body weight (70 kg for adults and 30 kg for children under 18);

[1] The risk value is referred to as the *incremental* risk because it is the incremental lifetime probability that an individual will develop cancer above and beyond the baseline probability posed by all other extant factors that contribute to a risk of developing cancer.

[2] A reach is a length of river, shoreline, or coastline with relatively uniform water flow characteristics. Thus, it is reasonable to assume that pollutant dischargers have a relatively uniform effect on concentrations within a reach.

LT = human lifetime (years);
CF_2 = conversion factor, years to days (365 days/year); and
SF = pollutant cancer potency factor $(mg/kg/day)^{-1}$.

The pollutants analyzed and their cancer potency factors are presented in Table 13.1. EPA used the relationship outlined above to estimate lifetime risk values for individuals in subsistence and recreational fishing households. The risks to recreational and subsistence households are estimated over two lifetime segments. Specifically, children living in recreational fishing households are assumed to consume 7.27 grams per day (0.007 kg/day) of freshwater/estuarine fish over an 18-year period (ages 0 to 18). Adults are assumed to consume 17.5 grams per day (0.018 kg/day) of freshwater/estuarine fish over a 52-year period (ages 18 to 70). Risks for individuals living in recreational and subsistence fishing households differ in the assumed consumption rates. Children living in subsistence fishing households are assumed to consume 60.58 grams per day (0.061 kg/day) of freshwater/estuarine fish over an 18-year period (ages 0-18). Adults in subsistence households are assumed to consume 142.4 grams per day (0.142 kg/day) of freshwater/estuarine fish over a 52-year period (ages 18 to 70). The total lifetime incremental risk for these households is calculated by summing the risks for both lifetime segments.

Fish consumption rates for adults are taken from the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (EPA, 2000a). Both these rates, 142.4 g/day for adult subsistence anglers and 17.5g/day for adult recreational anglers, are used for the specific sub-population that they represent. EPA was not able to break the data supporting these rates down by gender or age group for use in this analysis.

EPA has determined that the fish consumption rate of 142.4 g/day for adult subsistence anglers falls within the range of the arithmetic mean of adult subsistence angler studies representative of the United States (EPA, 1998). The value represents the average consumption rate for this population of anglers. It represents uncooked, fresh and estuarine finfish and shellfish. This rate is reported on an uncooked basis because pollutant concentration data is reported on an uncooked weight basis. Similarly, the fish consumption rate of 17.5 g/day falls within the average consumption rate for adult recreational anglers. This rate also represents uncooked, fresh and estuarine finfish and shellfish.[3]

Fish consumption rates for children in recreational angling households are based on West et al. (1989) in the Exposure Factors Handbook (EPA 1997c). This study has the most specific data for this population group and cites an intake of 7.27 grams/day of freshwater and estuarine fish for children in recreational angling households. For children in subsistence angling households, the consumption rate was extrapolated from the 7.27 grams/day rate for children in recreational angling households using the proportional relationship between consumption rates for adult subsistence and recreational anglers (142.4 grams/day divided by 17.5 grams/day). The consumption rate for children in subsistence angling households is calculated to be 60.58 grams/day.

Currently, data on marine fish consumption rates for recreational anglers and subsistence anglers are not readily available. Given that there are few **marine reaches** affected by the MP&M effluent guideline, EPA decided to use the fresh and estuarine fish consumption rates in lieu of marine fish consumption rates. This may result in underestimation of benefits, however, it may also be argued that few subsistence fishers eat fresh/estuarine fish and marine fish at the same rate.

[3] For detail see memorandum *Fish Consumption Rates* by Lynn Zipf (EPA, 2002).

Table 13.1: Cancer Potency Factors for MP&M Pollutants			
CAS Number	**Regulated Pollutant**	**Cancer Potency Factor (mg/kg/day)[a]**	**Drinking Water Criterion?**
62533	Aniline	0.0057	
62759	Nitrosodimethylamine, N-	51	
67663	Trichloromethane	0.0061	Yes
75003	Chloroethane	0.0029	
75092	Dichloromethane	0.0075	Yes
75354	Dichloroethene, 1,1-	0.6	Yes
78591	Isophorone	0.00095	
79016	Trichloroethene	0.011	Yes
86306	Nitrosodiphenylamine, N-	0.0049	
117817	Bis(2-ethylhexyl) phthalate	0.014	Yes
123911	Dioxane, 1,4-	0.011	
127184	Tetrachloroethene	0.052	Yes
7440382	Arsenic	1.5	Yes

[a] The cancer potency factor is the incremental probability of developing cancer over a lifetime resulting from ingestion of the indicated chemical at the rate of one milligram per day per kilogram of body mass. For the incremental rates of exposure in this analysis and assuming reasonable background chemical exposures, the potency factor may be reasonably assumed to be a linear constant.

Source: U.S. EPA (1998/99); U.S. EPA (1997a).

The pollutant-specific risks to recreational and subsistence anglers from MP&M facility discharges were then summed *across pollutants* for each type of angler, to obtain incremental risks for each population group from each facility's discharge. EPA developed separate estimates of cancer risk for each combination of angler type and facility discharging at least one pollutant with a cancer risk factor. The total change in probability of developing cancer from exposure to *more than one* MP&M pollutant is assumed to be the sum of the incremental risk effects from each pollutant: that is, the effects of the individual pollutants are assumed to be linearly additive.[4] The annual increased risk of cancer was estimated by dividing the increased lifetime risk values by 70 (an estimate of lifetime).

b. Estimating the affected population

The population exposed to contaminated fish and thus expected to benefit from reduced discharges includes recreational and subsistence anglers who fish the affected reaches, as well as members of such anglers' households. The geographic area from which anglers would travel to fish a reach is assumed to include only those counties that abut a given reach.[5] This assumption is based on the finding in the *1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* that 65 percent of anglers travel less than 50 miles to fish (U.S. Department of the Interior, 1993). The average diameter of the counties abutting the reaches receiving discharges from the sample MP&M facilities is approximately 20 miles. Given that counties may have different shapes and that the road distance to the fishing site is likely to be greater than a straight line, the MP&M approach is likely to account for the majority of anglers that are likely to fish the affected reach. It is, however, likely to

[4] Note that the assumption of linear additivity of cancer risk effects applies not only to the combination of pollutants from a single facility but also to the combined effects of multiple facility discharges. When more than one MP&M facility discharges to the same affected waterway a circumstance found to occur with some frequency in the sample facility data the combination of the multiple facility discharges may be accounted for by simply analyzing the effects of each facility independently. The cancer effects from multiple facilities can be aggregated to estimate cancer cases in the exposed population.

[5] The exposed, and thus potentially benefiting, population would also include a category of "all other individuals" who consume freshwater and estuarine fish. Although these individuals are expected to have a much lower average daily consumption rate than anglers in the adjacent counties, they nevertheless would likely receive some benefit from reduced exposure to pollutants through fish consumption. This analysis omits this consumption category and the associated benefit estimate.

introduce a downward bias into the estimate of the affected population. Given that anglers tend to travel farther to visit sites of very good or exceptional quality, the magnitude of this bias will depend on the fishing quality of the affected sites.

Estimating the number of persons fishing a reach involved the following steps:

- estimating the licensed fishing population in counties abutting MP&M reaches;
- estimating the population of subsistence fishermen in counties abutting MP&M reaches;
- estimating the fraction of the total fishing population in counties abutting an MP&M reach that fish the MP&M reach and, from that fraction, the size of population expected to fish each MP&M reach;
- adjusting the calculated fishing populations for the presence of fish advisories; and
- including family members in the exposed population estimates.

❖ *Estimating the licensed fishing population in counties abutting MP&M reaches*

The number of fishing licenses sold in counties abutting MP&M reaches is assumed to approximate the number of anglers residing in the abutting counties. EPA excluded the nonresident, one-day, and three-day license categories from the total number of licenses used in this analysis. Data on fishing licenses are not available for every state in which MP&M facilities are located. EPA used state-level data to estimate the number of fishing licenses per county for those states for which county-level data were not assembled. Total state licenses were apportioned to counties based on the ratio of total population in the county abutting a discharge reach to total state population. Where an MP&M reach spans more than one county, fishing licenses were summed across all counties abutting the discharge reach. Where a reach lies in more than one state, EPA separately calculated the number of licenses for the abutting county(ies) based on the fishing license and county population data for the respective states.

EPA's analysis does not account for recreational anglers who do not purchase licenses as required by law. This may result in a significant underestimate of the fishing population at risk from exposure to MP&M pollutants. For example, the *1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* found that 34 percent of the anglers (16 years of age and older) did not have licenses (U.S. Department of the Interior, 1996).

❖ *Estimating the population of subsistence fishermen in counties abutting MP&M reaches*

Although fishing licenses may be sold to subsistence fishermen, many of these individuals do not purchase fishing licenses. The extent of subsistence fishing in the U.S. or in individual states is not generally known. For this analysis, EPA assumed that the number of subsistence fishermen would be an additional 5 percent of the licensed fishing population.[6] That is, after estimating the licensed fishing population in counties abutting MP&M reaches, EPA added 5 percent to this value as the estimated number of subsistence fishermen.[7]

❖ *Estimating the population fishing an MP&M reach*

EPA assumed that fishing activity among anglers residing within counties abutting a discharge reach is distributed evenly among all reach miles within those counties. Thus, the number of anglers who fish an MP&M reach was estimated by computing the length of the reach as a percentage of total reach miles within corresponding counties and multiplying the estimated ratio by the total fishing population in counties abutting the reach.

❖ *Adjusting for fish advisories*

For MP&M reaches where fish advisories are in place (typically due to non-MP&M regulated pollutants such as dioxin and mercury), EPA assumed that some proportion of anglers would adhere to the advisory and not fish those reaches (U.S. EPA, 1999a). Past studies suggest that anglers have a high, although not complete, level of awareness of fish advisories. These studies further suggest that while anglers may change their behavior in response to fish consumption advisories, they do not necessarily refrain from fishing in these reaches or consuming fish taken from reaches under an advisory. For example,

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[6] It is important to estimate recreational and subsistence populations separately because fish consumption rates for subsistence anglers are considerably higher than those for recreational anglers.

[7] The environmental justice analysis presented in Chapter 17 of this report shows that the percent of residents living below the poverty level in the counties affected by MP&M discharges ranges from 7.4 to 25.2. Thus, the assumption that subsistence anglers are an additional 5% of the licensed fishing population is likely to provide a reasonable estimate of the subsistence anglers population.

studies conducted by Belton et al (1986), Knuth and Velicer (1990), Silverman (1990), West et al. (1989), Connelly, Knuth, and Bisogni (1992), and Connelly and Knuth (1993) indicate that 50 to 87 percent of anglers surveyed were aware of state fish advisories on water bodies where they fish.

These studies also indicate that only 10 to 34 percent of anglers who were aware of advisories modified their fishing behavior in response by no longer fishing a particular location, changing the location in which they fish, or taking fewer fishing trips. However, 13 to 68 percent of anglers who were aware of advisories changed their consumption or preparation habits in response to advisories. The study by Knuth and Velicer (1990) also found some confusion among anglers regarding which waters were under advisory: 37 percent of fishermen actually fishing in waters under advisory reported that they were fishing in uncontaminated waters.

On the basis of these data, EPA assumed that recreational fishing activity would be 20 percent less on reaches subject to an advisory than would otherwise be estimated. EPA also assumed that fish advisories *do not* affect fishing participation by subsistence anglers; thus, no adjustment was made to the estimates of the subsistence fishing population based on the presence of fish advisories.

The assumed 20 percent decrease in recreational fishing could lead to either an overestimate or underestimate of the risk associated with consumption of contaminated fish. For one thing, anglers who change locations may simply be switching to other locations where advisories are in place and therefore maintain or increase their current risk. Also, those who continue to fish contaminated waters may change their consumption and preparation habits to minimize the risks. Data on the specific fish advisories was pulled from EPA's on-line Listing of Fish and Wildlife Advisories (U.S. EPA, 1999a).

❖ ***Including family members in the exposed population estimates***

EPA assumed that, in addition to anglers themselves, families of anglers would also consume fish taken from waters affected by MP&M facility discharges. Therefore, for each MP&M reach, EPA multiplied the estimated numbers of recreational and subsistence anglers fishing the affected reaches by 2.65, the size of the average U.S. household in 1996 based on Current Population Reports, (U.S. Bureau of the Census, 1997). These calculations yielded the household populations of recreational and subsistence anglers who are estimated to consume fish from the reach to which the MP&M facility discharges, either directly or indirectly through a POTW. EPA expects that family members will benefit from reduced MP&M industry discharges by consuming fish that has lower levels of pollutant contamination.

c. Calculating the change in the number of cancer events in the exposed population

EPA calculated the number of cancer cases associated with the pollutant discharges (baseline and post-compliance) from each facility by multiplying the incremental cancer risk value for the two population classes times the estimated sizes of the population classes living near the facility. The product of the incremental risk value and the population size yields the number of annual cancer events in the given population class estimated to result from consumption of fish taken from waterways affected by MP&M pollutant discharges. Summing the values for the recreational and subsistence fishing household classes yields the total number of cancer cases associated with the sample facility discharges. Because the number of cancer cases apply to *sample* facilities, EPA extrapolated the sample results to the total MP&M population by multiplying the result obtained for each sample facility by its sample weight and summing the sample-weighted facility results. The formula follows:

$$TCC_{fc} = \sum_{i}^{n} Wt_i \times ((POP_{i,sprt} \times Risk_{i,sprt}) + (POP_{i,sbst} \times Risk_{i,sbst})) \qquad (13.2)$$

where:

TCC_{fc}	=	total national estimate of annual cancer cases associated with consumption of contaminated fish tissue (baseline or post-compliance);
Wt_i	=	facility sample weight *i* (*i* = 1 to *N* facilities, where *N* is the number of facilities in the sample);
$POP_{i,sprt}$	=	exposed population in recreational fishing households for the reach to which facility *i* discharges (with adjustments as indicated for the presence of fish consumption advisories);
$POP_{i,sbst}$	=	exposed population in subsistence fishing households for the reach to which facility *i* discharges;

$Risk_{i,sprt}$ = incremental cancer risk from fish consumption in the recreational fishing household population associated with MP&M pollutant discharges from facility *i*; and
$Risk_{i\ sbst}$ = incremental cancer risk from fish consumption in the subsistence fishing household population associated with MP&M pollutant discharges from facility *i*.

These values were calculated for the baseline and post-compliance discharge cases. The *difference* is the number of cancer cases estimated to be avoided annually through the fish consumption pathway as a result of the final regulation.

13.1.2 Cancer from Drinking Water Consumption

The analysis of reduced cancer incidence via the drinking water pathway involves three analytical steps that are largely parallel to those performed for the fish consumption pathway:

- estimating cancer risk to an exposed individual from consumption of contaminated drinking water,
- estimating the population that would benefit, and
- calculating the change in the number of cancer events in the exposed population.

The major differences in the analysis for the drinking water pathway involve the identification of the exposed population and the analysis of pollutant discharge effects in both the reach to which a facility discharges and reaches downstream of the discharge point.

a. Estimating cancer risk from drinking water consumption

Estimating cancer risk from consumption of drinking water affected by MP&M discharges requires calculating in-waterway pollutant concentrations in locations where drinking water treatment systems draw water for public consumption. This analysis involves three elements:

- estimating in-waterway pollutant concentrations for each pollutant in the reach to which a facility directly or indirectly discharges. The method and formulas for this calculation are identical to those described for the analysis of cancer effects for the fish consumption pathway.
- estimating the pollutant concentrations over a distance of 500 kilometers downstream from each facility's discharge reach, using an exponential decay model in which pollution concentrations diminish below the initial point of discharge (e.g., dilution, adsorption, partitioning, volatilization, and hydrolysis). Methods used to calculate downstream pollutant concentrations are described in more detail in Appendix H.
- identifying the location of any drinking water intakes in the initial and downstream reaches where pollutant concentrations were calculated and assigning pollutant concentration values to each relevant intake point. The EPA's Safe Drinking Water Information System ***(SDWIS)*** file in the Risk Screening Environmental Indicator ***(RSEI)*** model provided information on drinking water intakes (U.S. EPA, 1999b).

Estimated pollutant concentrations at each drinking water intake determines cancer risk. EPA assumed drinking water treatment systems will reduce concentrations to below adverse effect thresholds for all chemicals for which EPA has published a drinking water criterion. Therefore, pollutants examined in the MP&M drinking water analysis include only six carcinogens for which current drinking water criteria are not available. See Table 13.1 for a list of the pollutants, their cancer potency factors, and drinking water criteria.

The formula for calculating the incremental risk to an individual resulting from the discharge of a given pollutant from a given facility at reaches with a known public drinking water intake is as follows:

$$Risk = \frac{C \times CF_1 \times CR \times EF \times ED}{BW \times LT \times CF_2} \times SF \qquad (13.3)$$

where:
Risk = incremental risk of incurring cancer from drinking water consumption (change in probability), calculated at each drinking water intake within 500 km of the initial discharge point;

C	=	pollutant concentration in surface water in the reach with an intake (µg/l);
CF_1	=	conversion factor, micrograms to milligrams (0.001 mg/µg);
CR	=	human consumption rate of water (1.24 l/day);
EF	=	exposure frequency (350 days/year);
ED	=	exposure duration (70 years);
BW	=	human body weight (70 kg);
LT	=	human lifetime (70 years);
CF_2	=	conversion factor (365 days/year); and
SF	=	pollutant cancer potency factor $(mg/kg/day)^{-1}$.

The consumption rate of 1.24 liters per day used in this analysis to represent the average daily consumption of drinking water by a person in the United States is taken from *Estimated Per Capita Water Ingestion in the United States* (EPA, 2000b). As recommended in the Exposure Factors Handbook (1997c), EPA uses an exposure frequency of 350 days per year to estimate the increased risk of cancer from consuming drinking water supplied by drinking water systems with intakes on local surface water bodies.

The incremental individual risk from each facility's pollutants are then summed over pollutants at each drinking water intake to calculate the incremental risk at each intake resulting from pollutant discharges by each upstream facility. The findings carried forward to the next step include the incremental cancer risk for each combination of facility and associated drinking water intake(s).

To estimate the annual increased risk of cancer in consumers served by drinking water intakes affected by MP&M discharges, the lifetime risk values were then divided by 70 years (an estimate of lifetime). These values were calculated for both the baseline and post-compliance discharge cases.

b. Estimating the benefiting population

The exposed population for each combination of discharging facility and drinking water intake is the general population served by the drinking water system for which the drinking water intake was identified. Safe Drinking Water Information System (SDWIS) file in the Risk Screening Environmental Indicator (RSEI) model provided information on drinking water intakes.

c. Calculating the changes in the number of cancer events

EPA calculated the number of cancer cases for baseline and post-compliance pollutant discharges for each combination of facility and affected drinking water intake by multiplying the incremental cancer risk value times the population served by the water system drawing water at the drinking water intake.

The total number of cancer cases associated with the facility discharges is the sum of cancer cases over all drinking water intakes. EPA extrapolated the sample results to the total MP&M population by multiplying the result for each sample facility by its sample weight and summing the sample-weighted facility results. Because incremental cancer effects are assumed to be linearly additive, cancer-risk effects are aggregated over facilities and drinking water intakes by simple addition of the effects calculated separately for each combination of facility and drinking water intake. The formula follows:

$$TCC_{dw} = \sum_{i}^{N} \sum_{j}^{M} Wt_i \times (POP_{i,j} \times Risk_{i,j}) \tag{13.4}$$

where:

TCC_{dw}	=	total national estimate of cancer cases associated with consumption of chemically-contaminated drinking water (baseline or post-compliance);
Wt_i	=	facility sample weight i (i = 1 to N facilities);
$POP_{i,j}$	=	population exposed to discharges by facility i at drinking water intake j (j = 1 to M water supply intakes); and
$Risk_{i,j}$	=	incremental cancer risk for discharges by facility i at drinking water intake j.

EPA calculated these values for the baseline and post-compliance discharge cases. The difference in the values is the number of drinking water associated cancer cases estimated to be avoided annually by reduced MP&M industry discharges.

13.1.3 Exposures above Non-cancer Health Thresholds

Exposed populations are also at risk of developing non-cancer health problems (including systemic, reproductive, immunological, neurological, or circulatory problems) from fish ingestion and water consumption. The common approach for assessing the risk of non-cancer health effects from the ingestion of a pollutant is to calculate a hazard quotient by dividing an individual's oral exposure to the pollutant, expressed as a pollutant dose in milligrams per kilogram body weight per day (mg/kg/day), by the pollutant's oral reference dose (RfD). An RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure that likely would not result in the occurrence of adverse health effects in humans, including sensitive individuals, during a lifetime. Toxicologists typically establish an RfD by applying uncertainty factors to the lowest- or ***no observed adverse effect level (NOAEL)*** for the critical toxic effect of a pollutant. A hazard quotient less than one means that the pollutant dose to which an individual is exposed is less than the RfD, and, therefore, presumed to be without appreciable risk of adverse human health effects. A hazard quotient greater than one means that the pollutant dose is greater than the RfD. RfDs are available for 77 of the 132 MP&M pollutants of concern. The pollutants analyzed and their RfDs are listed in Table 13.2.

Table 13.2: RfDs for MP&M Pollutants

CAS Number	Regulated Pollutant	RfD (mg/kg/day)	Drinking Water Criterion? [a]	Target Organ and Effects
83329	Acenaphthene	0.060	No	Liver toxicity
67641	Acetone	0.100	No	Increased liver and kidney weights; nephrotoxicity
98862	Acetophenone	0.100	No	General toxicity
107028	Acrolein	0.020	No	Cardiovascular toxicity[b]
7429905	Aluminum	1.000	Yes	Renal failure, intestinal contraction interference, adverse neurological effects[c]
120127	Anthracene	0.300	No	
7440360	Antimony	0.000	Yes	Longevity, blood glucose, cholesterol
7440382	Arsenic	0.000	Yes	Hyperpigmentation, keratosis and possible vascular complications
7440393	Barium	0.070	Yes	Increased kidney weight
65850	Benzoic acid	4.000	No	
100516	Benzyl alcohol	0.300	No	Forestomach, epithelial hyperplasia
7440417	Beryllium	0.002	Yes	Small intestinal lesions
92524	Biphenyl	0.050	No	Kidney damage
117817	Bis(2-ethylhexyl) phthalate	0.020	Yes	Increased relative liver weight
7440428	Boron	0.090	No	Testicular atrophy, spermatogenic arrest
85687	Butyl benzyl phthalate	0.200	No	Significantly increased liver-to-body weight and liver-to-brain weight ratios
7440439	Cadmium	0.001	Yes	Significant proteinuria (protein in urine)
75150	Carbon disulfide	0.100	No	Fetal toxicity, malformations
108907	Chlorobenzene	0.020	No	Histopathologic changes in liver
75003	Chloroethane	0.400	No	
7440473	Chromium	1.500	Yes	Renal tubular necrosis (kidney tissue decay)[c]
18540299	Chromium hexavalent	0.003	Yes	Reduced water consumption
7440484	Cobalt	0.060	No	Heart effects[c]
7440508	Copper	0.040	Yes	Gastrointestinal effects, liver necrosis[c]
95487	Cresol, o-	0.050	No	Decreased body weights and neurotoxicity.

Table 13.2: RfDs for MP&M Pollutants				
CAS Number	Regulated Pollutant	RfD (mg/kg/day)	Drinking Water Criterion? [a]	Target Organ and Effects
106445	Cresol, p-	0.005	No	Central nervous system hypoactivity and respiratory system distress
57125	Cyanide	0.020	Yes	Weight loss, thyroid effects and myelin degeneration
75354	Dichloroethene, 1,1-	0.009	Yes	Toxic effects on kidneys, spleen, lungs[c]; hepatic lesions
75092	Dichloromethane	0.060	Yes	Liver toxicity
60297	Diethyl ether	0.200	No	Depressed body weights
68122	Dimethylformamide, N,N-	0.100	No	Liver and gastrointestinal system effects
105679	Dimethylphenol, 2,4-	0.020	No	Clinical signs (lethargy, prostration, and ataxia) and hematological changes
84742	Di-n-butyl phthalate	0.100	No	Increased mortality
51285	Dinitrophenol, 2,4-	0.002	No	Cataract formation
606202	Dinitrotoluene, 2,6-	0.001	No	Mortality, central nervous system neurotoxicity, blood heinz bodies and methemoglobinemia, bile duct hyperplasia, kidney histopathology
117840	Di-n-octyl phthalate	0.020	No	Kidney and liver increased weights, liver increased SGOT and SGPT activity
122394	Diphenylamine	0.025	No	Decreased body weight, and increased liver and kidney weights
100414	Ethylbenzene	0.100	Yes	Liver and kidney toxicity
206440	Fluoranthene	0.040	No	Nephropathy, increased liver weights, hematological alterations, clinical effects
86737	Fluorene	0.040	No	Decreased red blood cell count, packed cell volume and hemoglobin
16984488	Fluoride	0.060	Yes	Objectionable dental fluorosis (soft, mottled teeth)
591786	Hexanone, 2-	0.040	No	Hypatotoxicity and nephrotoxcity[d]
7439896	Iron	0.300	Yes	Liver, diabetes mellitus, endocrine disturbance, and cardiovascular effects[d]
78831	Isobutyl alcohol	0.300	No	Hypoactivity and ataxia
78591	Isophorone	0.200	No	Kidney pathology
7439965	Manganese	0.140	Yes	Central nervous system effects
78933	Methyl ethyl ketone	0.600	No	Decreased fetal birth weight
108101	Methyl isobutyl ketone	0.080	No	Lethargy, increased liver and kidney weights and urinary protein
80626	Methyl methacrylate	1.400	No	Increased kidney to body weight ratio
91576	Methylnaphthalene, 2-	0.020	No	
7439987	Molybdenum	0.005	No	Increased uric acid
91203	Naphthalene	0.020	No	Decreased body weight
7440020	Nickel	0.020	Yes	Decreased body and organ weights
100027	Nitrophenol, 4-	0.008	No	
59507	Parachlorometacresol	2.000	No	
108952	Phenol	0.600	No	Reduced fetal body weight in rats
7723140	Phosphorus (elemental)	0.000	No	Parturition mortality; forelimb hair loss

Table 13.2: RfDs for MP&M Pollutants

CAS Number	Regulated Pollutant	RfD (mg/kg/day)	Drinking Water Criterion? [a]	Target Organ and Effects
129000	Pyrene	0.030	No	Kidney effects (renal tubular pathology, decreased kidney weights)
110861	Pyridine	0.001	No	Increased liver weight
7782492	Selenium	0.005	Yes	Clinical selenosis (hair or nail loss)
7440224	Silver	0.005	Yes	Argyria (skin discoloration)
100425	Styrene	0.200	Yes	Red blood cell and liver effects
127184	Tetrachloroethene	0.010	Yes	Liver toxicity, weight gain
7440280	Thallium	0.000	Yes	Liver toxicity, gastroenteritis, degeneration of peripheral and central nervous system[b]
7440315	Tin	0.600	No	Kidney and liver lesions
7440326	Titanium	4.000	No	
108883	Toluene	0.200	Yes	Changes in liver and kidney weights
79016	Trichloroethene	0.006	Yes	Bone marrow, central nervous system, liver, kidneys[d]
75694	Trichlorofluoromethane	0.300	No	Survival and histopathology
67663	Trichloromethane	0.010	Yes	Fatty cyst formation in liver
7440622	Vanadium	0.007	No	Kidney and central nervous system effects[b]
108383	Xylene, m-	2.000	Yes	Central nervous system hyperactivity, decreased body weight
179601231	Xylene, m- & p-*	2.000	Yes	
95476	Xylene, o-	2.000	Yes	Central nervous system hyperactivity, decreased body weight
136777612	Xylene, o- & p-*	2.000	Yes	
7440666	Zinc	0.300	Yes	47% decrease in erythrocyte superoxide dismutase (ESOD) concentration in adult human females after 10 weeks of zinc exposure
137304	Ziram \ Cymate	0.020	No	

[a] "Yes"= there is a published drinking water criterion for a given chemical.
[b] Reference dose based on a no observed adverse effect level (NOAEL). Health effects summarized from Amdur, M.O.; Doul, J.; and Klaassen, C.D.,eds. 1991. *Cassarett and Doul's Toxicology*, 4th edition.
[c] Target organ and effects summarized from Wexler, P., ed. 1998. *Encyclopedia of Toxicology,* Volumes 1-3.
[d] Target organ and effects summarized from Amdur, M.O.; Doul, J.; and Klaassen, C.D.,eds. 1996. *Cassarett and Doul's Toxicology*, 5th edition.

Source: U.S. EPA (1998/99); U.S. EPA (1997a).

EPA guidance for assessing exposures to mixtures of pollutants recommends calculating a hazard index (HI) by summing the individual hazard quotients for those pollutants in the mixture that affect the same target organ or system (e.g., the kidneys, the respiratory system). For example, for three liver toxicants discharged from an MP&M facility (pollutant A with a hazard index of 0.10, pollutant B with a hazard index of 0.05, and pollutant C with a hazard index of 0.15), the combined hazard index is 0.30. HI values are interpreted similarly to hazard quotients; values below one are generally considered to suggest that exposures are not likely to result in appreciable risk of adverse health effects during a lifetime, and values above one are generally cause for concern, although an HI greater than one does not necessarily suggest a likelihood of adverse effects.

To evaluate the potential benefits of reducing the in-stream concentrations of 76 pollutants that cause non-cancer health effects, EPA estimated target organ-specific HIs for drinking water and fish ingestion exposures in both the baseline and post-compliance scenarios. HI is calculated for each discharge reach associated with one or more MP&M sample facilities by dividing the estimated ingestion rate of each pollutant by the RfD value for the pollutant. The formula follows:

$$HI = \sum_{k}^{K} \frac{DCR_k}{RfD_k} \tag{13.5}$$

where:

HI	=	hazard index for the pollutants discharged from a facility and ingested by a specific consumption pathway;
DCR_k	=	estimated daily consumption rate per kilogram of body mass for pollutant *k* via a specific consumption pathway (mg/kg/day);
RfD_k	=	reference dose for pollutant *k* (mg/kg/day); and
K	=	number of pollutants affecting a given organ or system.

Daily consumption rate (DCR) per kilogram of body mass for pollutant k is estimated as follows:

$$DCR_k = \frac{C \times CF_1 \times CR \times BCF}{BW} \tag{13.6}$$

where:

DCR_k	=	estimated daily consumption rate per kilogram of body mass for pollutant *k* via a specific consumption pathway (mg/kg/day);
C	=	pollutant concentration in surface water in the MP&M reach (µg/l);
CF_1	=	conversion factor, micrograms to milligrams (0.001 mg/µg);
CR	=	human consumption rate of water (mg/day);
BCF	=	bioconcentration factor for pollutant *k*;
BW	=	human body weight (kg).

These HIs are calculated separately for the fish and water consumption pathways. The fish consumption pathway was further divided into recreational and subsistence fish consumption rates. The procedures and formulas for estimating the in-waterway concentrations and ingestion of pollutants by exposed populations are the same as those used for the fish consumption and drinking water cancer analyses. The only exception is that the analysis of non-cancer health pathways was performed for the discharge reach only and not for reaches downstream, due to time and resource constraints. As a result, this analysis underestimates populations exposed to non-cancer risks via drinking water pathways

EPA then combined estimates of the numbers of individuals in the exposed populations with the HIs for the populations to determine how many individuals might be expected to realize reduced risk of non-cancer health effects in the post-compliance scenario. The basis for identifying exposed populations is the same as that described for the analysis of reduced incidence of cancer via the fish consumption and drinking water consumption pathways.[8] The *shift* in populations from a *higher* to a *lower* HI value from the baseline to post-compliance cases is the quantitative measure of benefits from this analysis. This analysis was limited in two primary ways:

- First, hazard indices estimated in this analysis may understate the actual potential for adverse health effects because this analysis considers contributions to non-cancer risk resulting only from MP&M facility discharges, and does not take into account other sources of exposure to MP&M pollutants or other chemicals that may contribute to an aggregate non-cancer risk. The net result is that the analysis understates the numerical value estimated for HIs, but the incremental change in HIs between the baseline and the final option would remain the same. EPA therefore evaluated potential incremental changes in non-cancer health risks over the entire range of hazard indices, including hazard indices below one.

- Second, EPA used mean individual exposure parameters and not the distribution of exposure parameters to estimate hazard indices for the populations affected by MP&M discharges.

The results from the non-cancer health risk analysis apply to sample discharge locations only. Analytic tractability issues prevented this analysis from being conducted on a sample-weighted national basis. EPA did not monetize these benefits.

[8] The exposed populations for the drinking water consumption pathway are those associated with drinking water intakes only in a facility's discharge reach.

13.1.4 Human Health AWQC

EPA used another approach to quantify reductions in health risk from the final MP&M regulation, based on the extent to which reduced MP&M discharges would decrease the occurrence of pollutant concentrations in affected waterways that exceed human health-based AWQC. This analysis provides a measure of the change in cancer and non-cancer health risk by comparing the number of discharge reaches exceeding health-based AWQC for regulated pollutants due to MP&M activities in the baseline to the number exceeding AWQC under the final option.

AWQC are set at levels to protect human health through ingestion of aquatic organisms and ingestion of water and aquatic organisms. Accordingly, reducing the frequency at which human health-based AWQC are exceeded should translate into reduced risk to human health. This measure should be viewed as an indirect indicator of reduced risk to human health, because it does not reflect the size of the exposed population and is not tied to changes in human health risk *per se*.[9]

EPA estimated the baseline concentrations of all MP&M pollutants for each reach to which one or more MP&M facilities discharge. The calculation of concentrations used the same in-waterway dilution and mixing model described in the analysis of cancer risk for the fish consumption pathway. The baseline concentrations were compared with human health-based AWQC values. (See Table 13.3 for a list of MP&M pollutants with AWQC values.) Reaches in which concentrations of one or more pollutants were estimated to exceed an AWQC value were identified as exceeding AWQC limits in the baseline.

This analysis was repeated using the post-compliance discharge values for the final option. Reaches estimated to have concentrations in excess of AWQC in the baseline but not in the post-compliance case were assessed as having substantial water quality improvements relative to human health-based criteria as a result of regulation. EPA deems such water quality improvements to be indicative of reduced risk to human health. Although not explicitly accounted for in this analysis, human health risk reductions are also likely to occur wherever in-waterway concentrations are reduced, regardless of whether or not they are reduced to levels below AWQC.

Table 13.3: MP&M Pollutants with Human Health-Based AWQC

CAS Number	Pollutant	Human Health-Based AWQC (ug/l)		Target Organ and Effects[a]
		Organisms Only	Water & Organisms	
83329	Acenaphthene	2700	1200	Liver, hepatotoxicity
67641	Acetone	2800000	3500	Increased liver and kidney weights; nephrotoxicity
98862	Acetophenone	98000	3400	General toxicity
107028	Acrolein	1000	410	Cardiovascular toxicity[c]
7429905	Aluminum	47000	20000	Renal failure, intestinal contraction interference, adverse neurological effects[d]
62533	Aniline	95	5.8	Spleen and body cavity
120127	Anthracene	6800	4100	No observed effects
7440360	Antimony	4300	14	Longevity, blood glucose, cholesterol
7440382	Arsenic	0.16	0.02	Liver, kidneys, lungs, bladder, and skin
7440393	Barium		1000	Increased kidney weight
65850	Benzoic acid	2900000	130000	No observed adverse effects
100516	Benzyl alcohol	810000	10000	Forestomach, epithelial hyperplasia
7440417	Beryllium	1100	66	Small intestinal lesions
92524	Biphenyl	1200	720	Kidney damage

[9] The following chapter uses this same information *in part* as a direct indicator of improved water quality.

Table 13.3: MP&M Pollutants with Human Health-Based AWQC

CAS Number	Pollutant	Human Health-Based AWQC (ug/l)		Target Organ and Effects[a]
		Organisms Only	Water & Organisms	
117817	Bis(2-ethylhexyl) phthalate	5.9	1.8	Liver
85687	Butyl benzyl phthalate	5200	3000	Significantly increased liver-to-body weight and liver-to-brain weight ratios
7440439	Cadmium	84	14	Significant proteinuria (protein in urine)
75150	Carbon disulfide	94000	3400	Fetal toxicity, malformations
108907	Chlorobenzene	21000	680	Histopathologic changes in liver
75003	Chloroethane	520	12	
1854029 9	Chromium hexavalent	2000	100	Reduced water consumption
7440473	Chromium	1000000	50000	Renal tubular necrosis (kidney tissue decay)[d]
7440508	Copper	1200	650	Gastrointestinal effects, liver necrosis[d]
106445	Cresol, p-	3100	170	Central nervous system hypoactivity and respiratory system distress
95487	Cresol, o-	30000	1700	Decreased body weights and neurotoxicity.
57125	Cyanide	220000	700	Weight loss, thyroid effects and myelin degeneration
117840	Di-n-octyl phthalate	39	37	Kidney and liver increased weights, liver increased SGOT and SGPT activity
84742	Di-n-butyl phthalate	12000	2700	Increased mortality
75354	Dichloroethene, 1,1-	3.2	0.057	Inconclusive
75092	Dichloromethane	1600	4.7	Liver, lungs
60297	Diethyl ether	770000	6900	Depressed body weights
131113	Dimethyl phthalate	2900000	310000	
68122	Dimethylformamide, N,N-	220000000	3500	Liver and gastrointestinal system effects
105679	Dimethylphenol, 2,4-	2300	540	Clinical signs (lethargy, prostration, and ataxia) and hematological changes
51285	Dinitrophenol, 2,4-	14000	70	Cataract formation
606202	Dinitrotoluene, 2,6-	900	34	Mortality, central nervous system neurotoxicity, blood heinz bodies and methemoglobinemia, bile duct hyperplasia, kidney histopathology
123911	Dioxane, 1,4-	2400	3.2	Liver, nasal cavity, gall bladder
122394	Diphenylamine	1000	470	Decreased body weight gain, and increased liver and kidney weights
100414	Ethylbenzene	29000	3100	Liver and kidney toxicity
206440	Fluoranthene	370	300	Nephropathy, increased liver weights, hematological alterations, clinical effects
86737	Fluorene	14000	1300	Decreased red blood cell count, packed cell volume and hemoglobin
591786	Hexanone, 2-	65000	1400	Hypatotoxicity and nephrotoxicity[b]
7439896	Iron		300	Liver, diabetes mellitus, endocrine disturbance, and cardiovascular effects[c]

Table 13.3: MP&M Pollutants with Human Health-Based AWQC				
CAS Number	Pollutant	Human Health-Based AWQC (ug/l)		Target Organ and Effects[a]
		Organisms Only	Water & Organisms	
78831	Isobutyl alcohol	1500000	10000	Hypoactivity and ataxia
78591	Isophorone	2600	36	Preputial gland
7439965	Manganese	100	50	Central nervous system effects
7439976	Mercury	0.051	0.05	
80626	Methyl methacrylate	2300000	48000	Increased kidney to body weight ratio
78933	Methyl ethyl ketone	6500000	21000	Decreased fetal birth weight
108101	Methyl isobutyl ketone	360000	2800	Lethargy, increased liver and kidney weights and urinary protein
91576	Methylnaphthalene, 2-	84	75	
91203	Naphthalene	21000	680	Decreased body weight
7440020	Nickel	4600	610	Decreased body and organ weights
100027	Nitrophenol, 4-	1100	220	
62759	Nitrosodimethylamine, N-	8.1	0.00069	Tumors observed at multiple sites
86306	Nitrosodiphenylamine, N-	16	5	Bladder tumors, reticulum cell sarcomas
59507	Parachlorometacresol	270000	56000	
108952	Phenol	4600000	21000	Reduced fetal body weight in rats
7723140	Phosphorus (elemental)	2.2	0.53	Parturition mortality; forelimb hair loss
129000	Pyrene	290	230	Kidney effects (renal tubular pathology, decreased kidney weights)
110861	Pyridine	5400	35	Increased liver weight
7782492	Selenium	11000	170	Clinical selenosis (hair or nail loss)
7440224	Silver	110000	170	Argyria (skin discoloration)
100425	Styrene	160000	6700	Red blood cell and liver effects
127184	Tetrachloroethene	3500	320	Liver toxicity, weight gain
7440280	Thallium	6.5	1.8	Liver toxicity, gastroenteritis, degeneration of peripheral and central nervous system
108883	Toluene	200000	6800	Changes in liver and kidney weights
79016	Trichloroethene	92	3.1	
75694	Trichlorofluoromethane	66000	9100	Survival and histopathology
67663	Trichloromethane	470	5.7	Kidneys
108383	Xylene, m-	100000	42000	Central nervous system hyperactivity, decreased body weight
136777612	Xylene, o- & p- (c)	100000	42000	
95476	Xylene, o-	100000	42000	Central nervous system hyperactivity, decreased body weight
179601231	Xylene, m- & p- (c)	100000	42000	
7440666	Zinc	69000	9100	47% decrease in erythrocyte superoxide dismutase (ESOD) concentration in adult human females after 10 weeks of zinc exposure

Table 13.3: MP&M Pollutants with Human Health-Based AWQC				
CAS Number	Pollutant	Human Health-Based AWQC (ug/l)		Target Organ and Effects[a]
		Organisms Only	Water & Organisms	
137304	Ziram \ Cymate	220000000	700	

[a] Information on target organs are not available for some pollutants.
[b] Reference dose based on a NOAEL. Health effects summarized from Amdur, M.O.; Doul, J.; and Klaassen, C.D.,eds. 1991. *Cassarett and Doul's Toxicology*, 4th edition/
[c] Target organ and effects summarized from Amdur, M.O.; Doul, J.; and Klaassen, C.D.,eds., C.D., ed. 1996. *Cassarett and Doul's Toxicology*, 5th edition.
[d] Target organ and effects summarized from Wexler, P., ed. 1998. *Encyclopedia of Toxicology*, Volumes 1-3.

Source: U.S. EPA (1980); U.S. EPA (1997a); U.S. EPA (1998/99).

13.2 RESULTS

EPA estimated the monetary value to society associated with reduced cancer risk from consumption of fish and drinking water affected by MP&M pollutant discharges. Little information is available about dose-response relationships for non-cancer health outcomes or about the monetary value of avoiding such health outcomes. As a result, EPA was unable to assign monetary values to the estimated reductions in non-cancer health risks. Such non-cancer health risks include systemic, reproductive, immunological, neurological, and circulatory problems. Although EPA was unable to assign monetary values to the latter two benefit measures for this regulation, the quantitative analyses of these events provide additional insight into the human health-related benefits likely to result from the final regulation.

The following sections present the findings from the analysis of each of the benefit measures.

13.2.1 Fish Consumption Cancer Results

Table 13.4 shows the estimated changes in incidence of cancer cases from consumption of MP&M pollutants in fish tissue and drinking water from regulatory compliance by option. The national-level analysis finds that the final regulation and the 433 Upgrade Options would lead to a marginal reduction in cancer cases resulting from consumption of contaminated fish tissue; correspondingly, monetary benefits estimated from reduced consumption of contaminated fish are negligible under all of these three regulatory alternatives. In contrast, the estimated reductions in carcinogen loadings under the Proposed/NODA Option would result in $3.68 million (2001$) in benefits to recreational and subsistence anglers.

Table 13.4: Estimated Avoided Cancer Cases and Value of Annual Benefits for the Final Option and Regulatory Alternatives[a,b]

Option	Fish Consumption		Drinking Water[c]	
	Avoided Cancer Cases per Year	Mean Value of Benefit (2001$)[c]	Avoided Cancer Cases per Year	Mean Value of Benefit (2001$)[d]
Final Option: Traditional Extrapolation	1.38E-05	$90	0	$0
Final Option: Post-Stratification Extrapolation	2.05E-05	$134	0	$0
Proposed/NODA Option[e]	0.57	$3,684,973	0.001	$6,536
Directs + 413 to 433 Upgrade Option	1.38E-05	$90	0	$0
Directs + All to 433 Upgrade Option	2.6E-05	$169	0	$0

[a] In this analysis, EPA did not consider reductions in discharges of one carcinogen n-nitrosodimethylanine (NDMA) due to the low number of detected values for that pollutant.
[b] Regulatory alternatives are based on the Traditional Extrapolation.
[c] Avoided cancer cases via the drinking water consumption pathway were not included for pollutants with drinking water criteria. EPA has published a drinking water criterion for seven of the 13 carcinogens and it is assumed that drinking water treatment systems will reduce concentrations of these chemicals to below adverse effect thresholds.
[d] Estimated value of one avoided cancer case (2001$): $6.5 million.
[e] The estimated benefits of the Proposed/NODA Option are not directly comparable to the final option alternatives. The total number of facilities reported for the Proposed/NODA Option analysis differs from the facility count reported for the final rule and the two upgrade options. After deciding in July 2002 not to consider the NODA option as the basis for the final rule, EPA performed no more analysis on the NODA option, including not updating facility counts and related analyses for the change in subcategory and discharge status classifications.

Source: U.S. EPA analysis.

The valuation of benefits is based on estimates of society's willingness-to-pay to avoid the risk of cancer-related premature mortality. Although it is not certain that all cancer cases will result in death, avoided cancer cases are valued on the basis of avoided *mortality* to provide a conservative estimate of benefits.

In this analysis, EPA used the $6.5 million estimate of the ***value of a statistical life saved (VSL)*** recommended in the *Guidelines for Preparing Economic Analysis* (EPA, 2000c). EPA based this value on its review and analysis of 26 policy-relevant value of life studies (EPA, 1997b). The reviewed studies used hedonic wage and contingent valuation analyses in labor markets to estimate the amounts that individuals would either be willing to pay to avoid slight increases in the risk of mortality, or would need to be compensated to accept a slight increase in risk of mortality.[10] EPA associated the ***willingness-to-pay (WTP)*** values estimated in these studies with small changes in the probability of mortality. To estimate a WTP value for avoiding certain or high probability mortality events, EPA extrapolated the smaller value to that for a 100 percent probability event.[11] The Agency used the resulting estimates of the value of a "statistical life saved" in regulatory analyses to value regulatory effects that are expected to reduce the incidence of mortality.

The monetary value of a statistical life saved used in this analysis corresponds to the value of unforeseen instant death with no significant period of morbidity. Because a long period of morbidity usually precedes death from cancer, the value of an avoided cancer case may be underestimated. Therefore, the estimated value of the human health benefit of the final regulation may be understated.

[10] The question analyzed in these studies is: How much more must a worker be paid to accept an occupation with a slightly higher risk of mortality?

[11] These estimates, however, do not represent the willingness-to-pay to avoid the certainty of death.

13.2.2 Drinking Water Consumption Cancer Results

Table 13.4 also shows the number of cancer cases estimated to be avoided for each pollutant analyzed for drinking water populations. The national-level analysis finds that the final regulation and the 433 Upgrade Options would lead to a marginal reduction in cancer cases resulting from consumption of contaminated drinking water; correspondingly, monetary benefits estimated from reduced consumption of contaminated drinking water are essentially zero under all of these three regulatory alternatives. As shown in Table 13.4, the Proposed/NODA Option would eliminate approximately 0.001 cancer cases per year. Annual monetary benefits from reduced cancer risk for the Proposed/NODA Option are estimated at $6,536 (2001$).

As noted in the preceding sections, EPA has established drinking water criteria for seven carcinogens. EPA assumes that public drinking water treatment systems will reduce these seven pollutants in the public water supply to levels that are protective of human health. To the extent that the final regulation reduces the concentration of MP&M pollutants to values that are below pollutant-specific drinking water criteria, public drinking water systems will accrue benefits in the form of reduced water treatment costs. EPA was not able to quantify such cost savings at the national level, however.

Public drinking water supply systems that currently employ various treatment technologies may also reduce concentrations of the six unregulated pollutants to the levels that are protective of human health. However, the Agency does not have information on specific treatment technologies used by the drinking water systems affected by MP&M discharges. It is not feasible to assess whether the technologies employed by the affected drinking water systems reduce concentrations of MP&M pollutants that don't have the published drinking water criteria without collecting detailed information on the affected drinking water systems. Thus, this analysis conservatively assumes that public water supply systems do not monitor pollutants that don't have published drinking water criteria and, as result, these pollutants may be passed through the affected drinking water supply systems.

13.2.3 Non-cancer Health Threshold Results

Table 13.5 summarizes baseline and post-compliance distributions of non-cancer health hazard indices and associated population estimates for each exposed population group for the final option. The shift in populations from higher to lower hazard score values between the baseline and post-compliance cases is the measure of benefit from reduced non-cancer health hazards.

Table 13.5: Change in Risk of Non-cancer Health Hazards from Reduced Exposure to MP&M Pollutants: Distribution of Hazard Indices[a]

Range of Ratios	Fish Consumption				Drinking Water Consumption			
	Baseline		Post-Compliance		Baseline		Post-Compliance	
	Population	Percent	Population	Percent	Population	Percent	Population	Percent
Final Option								
Ratio = 0.00	0	0%	122,865	12.05%	39,822,464	97.48%	40,723,280	99.69%
$0.00 - 10^{-6}$	121,814	11.95%	103,103	10.12%	1,029,333	2.52%	128,517	0.31%
$10^{-6} - 10^{-3}$	680,301	66.73%	578,122	56.72%	0	0%	0	0%
10^{-3} - 1.00	217,201	21.31%	215,226	21.11%	0	0%	0	0%
Score > 1.00	0	0%	0	0%	0	0%	0	0%
Totals	1,019,316	100%	1,019,316	100%	40,851,797	100	40,851,797	100%
Proposed/NODA Option[b]								
Ratio = 0.00	0	0%	342,040	8.17%	0	0%	4,308,352	10.95%
$0.00 - 10^{-6}$	872,003	20.82%	796,003	19.01%	36,552,343	92.93%	33,667,164	85.59%
$10^{-6} - 10^{-3}$	2,221,724	53.04%	2,310,376	55.16%	2,783,100	7.07%	1,359,927	3.46%
10^{-3} - 1.00	1,054,627	25.18%	737,312	17.60%	0	0%	0	0%
Score > 1.00	40,630	0.97%	3,253	0.08%	0	0%	0	0%
Totals	4,188,984	100%	4,188,984	100%	39,335,442	100%	39,335,442	100%
Directs + 413 to 433 Upgrade Option								
Ratio = 0.00	0	0.0%	169,106	16.59%	39,822,464	97.48%	40,723,280	99.69%
$0.00 - 10^{-6}$	121,814	11.95%	91,255	8.96%	1,029,333	2.52%	128,517	0.31%
$10^{-6} - 10^{-3}$	680,301	66.73%	559,690	54.91%	0	0%	0	0%
10^{-3} - 1.00	217,201	21.31%	199,265	19.54%	0	0%	0	0%
Score > 1.00	0	0%	0	0%	0	0%	0	0%
Totals	1,019,316	100%	1,019,316	100%	40,851,797	100%	40,851,797	100%
Directs + All to 433 Upgrade Option								
Ratio = 0.00	0	0.0%	169,106	16.59%	39,822,464	97.48%	40,723,280	99.69%
$0.00 - 10^{-6}$	121,814	11.95%	91,255	8.96%	1,029,333	2.52%	128,517	0.31%
$10^{-6} - 10^{-3}$	680,301	66.73%	563,526	55.28%	0	0%	0	0%
10^{-3} - 1.00	217,201	21.31%	195,429	19.17%	0	0%	0	0%
Score > 1.00	0	0%	0	0%	0	0%	0	0%
Totals	1,019,316	100%	1,019,316	100%	40,851,797	100%	40,851,797	100%

[a] This analysis addresses only 76 of 132 chemicals of concern, excludes background exposures, and is based only on *sample* facility discharges and associated populations. The exposed population values are not national estimates of the populations that would benefit by reduced risk of non-cancer health hazards.
[b] The estimated benefits of the Proposed/NODA Option are not directly comparable to the final option alternatives. The total number of facilities reported for the Proposed/NODA Option analysis differs from the facility count reported for the final rule and the two upgrade options. After deciding in July 2002 not to consider the NODA option as the basis for the final rule, EPA performed no more analysis on the NODA option, including not updating facility counts and related analyses for the change in subcategory and discharge status classifications.

Source: U.S. EPA analysis.

For each discharge reach, EPA selected the maximum of the target organ-specific hazard index values calculated for a given discharge reach to characterize the potential for adverse non-cancer health affects from exposure to MP&M pollutants among exposed individuals. The results of EPA's analysis suggest that HIs for individuals in the exposed populations may decrease after facilities comply with the final rule (see Table 13.5 for detail). Increases in the percentage of exposed populations that would be exposed to no risk of non-cancer adverse human health effects due to the MP&M discharges occur in both the fish and drinking water analyses. The shift to lower hazard indices should be considered in conjunction with the finding that the hazard indices for incremental exposures to pollutants discharged by MP&M facilities (for which reference doses are available) are less than one in the baseline analysis for the entire population associated with sample facilities. Whether the incremental shifts in hazard indices are significant in reducing absolute risks of non-cancer adverse human health effects is uncertain and will depend on the magnitude of contaminant exposures for a given population from risk sources not accounted for in this analysis.

Table 13.5 shows that the Proposed/NODA Option and the 433 Upgrade Options would result in similar shifts in the exposed populations from higher to low hazard index values. All of these three alternative regulatory options would increase the population with a zero incremental risk of non-cancer health effects from exposure to MP&M pollutants.

Although EPA was unable to associate an economic value with changes in the number of individuals exposed to pollutant levels likely to result in non-cancer health effects, the reductions in health risk indicated by this benefit measure further indicate that the final regulation can be expected to yield human health benefits.

13.2.4 Human Health AWQC Results

The final human health benefit category is the reduced occurrence of pollutant concentrations that are estimated to exceed human health-based AWQC. This analysis provides an alternative measure of the expected reduction in risk to human health. EPA estimates that in-stream concentrations of 4 pollutants (i.e., arsenic, iron, manganese, and n-nitrosodimethylamine) will exceed human health criteria for consumption of water and organisms in 78 receiving reaches nationwide as the result of baseline MP&M pollutant discharges. EPA estimates that there are human health AWQC exceedances caused by n-nitrosodimethylamine (NDMA). EPA did not consider NDMA pollutant reductions in its benefits analyses because of low number of detected values for that pollutant. EPA estimates that the final rule will not eliminate the occurrence of concentrations in excess of human health criteria for consumption of water and organisms and for consumption of organisms on any of the reaches on which baseline discharges are estimated to cause concentrations in excess of AWQC values.

EPA's analysis of the 433 Upgrade Options yields similar results. However, the Directs +All to 433 option would reduce the number of pollutants causing in-stream concentrations to exceed the human health-based AWQC values from 4 to 2 (i.e., exceedances from iron and manganese are eliminated). As shown in Table 13.6, the Proposed/NODA Option would not result in a significant reduction in the number of reaches that are estimated to exceed human health-based AWQC for consumption of water and organisms under the baseline discharge level. The Proposed/NODA option, however, eliminates human health-based AWQC for consumption of organisms only on 69 (35 percent) of the 197 reaches, in which in-stream pollutant concentrations exceeded the relevant criteria in the baseline. The Agency points out that analytic results corresponding to the Proposed/NODA Option are not directly comparable to the analytic results corresponding to the final rule alternatives due to the inconsistent baseline conditions (see Chapter 5 of this report for detail).

Table 13.6: MP&M Discharge Reaches with Pollutant Concentrations Exceeding Human Health-Based AWQC Limits and Reductions Achieved[a]

Category	Human Health Water and Organisms		Human Health Organisms Only	
	Number of Reaches	Number of Pollutants	Number of Reaches	Number of Pollutants
Final Option: Traditional Extrapolation				
Baseline	78	4	21	1
Post-Compliance	78	4	21	1
Percent Reduction	0.0%		0.0%	
Final Option: Post-Stratification Extrapolation				
Baseline	112	4	21	1
Post-Compliance	112	4	21	1
Percent Reduction	0.0%		0.0%	
Proposed/NODA Option[b]				
Baseline	5,852	26	197	12
Post-Compliance	5,789	21	128	9
Percent Reduction	1.1%		34.6%	
413 to 433 Upgrade Option				
Baseline	78	4	21	1
Post-Compliance	78	4	21	1
Percent Reduction	0.0%		0.0%	
Directs + All to 433 Upgrade Option				
Baseline	78	4	21	1
Post-Compliance	78	2	0	0
Percent Reduction	0.0%		100.0%	

[a] Regulatory alternatives are based on the Traditional Extrapolation.
[b] The estimated benefits of the Proposed/NODA Option are not directly comparable to the final option alternatives. The total number of facilities reported for the Proposed/NODA Option analysis differs from the facility count reported for the final rule and the two upgrade options. After deciding in July 2002 not to consider the NODA option as the basis for the final rule, EPA performed no more analysis on the NODA option, including not updating facility counts and related analyses for the change in subcategory and discharge status classifications.

Source: U.S. EPA analysis.

13.3 Limitations and Uncertainties

This section discusses limitations and uncertainties in the human health benefits analysis. The analysis does not include all possible human health benefits, and therefore does not provide a comprehensive estimate of the total human health benefits associated with the final rule. Quantification of changes in human health risk described in this chapter are not possible for all pollutants whose discharges will be reduced by the final regulation. Due to current research limitations, cancer potency factors, reference doses, and AWQC are not available for 6 metals, 27 organics, 8 nonconventional pollutants, and 3 conventional pollutants. The methodologies used also involve significant simplifications and uncertainties, as described below. Whether these simplifications and uncertainties, taken together, are likely to lead to an understatement or overstatement of the estimated economic values *for the human health benefits that were analyzed* is not known.

13.3.1 Sample Design & Analysis of Benefits by Location of Occurrence

The MP&M industries are estimated to include over 43,867 facilities nationwide that generate wastewater while processing metal parts, metal products, and machinery. Many of these facilities are quite small and, individually, discharge relatively small quantities of pollutants. Most individual facilities are not likely to have a significant adverse impact on human health at any one MP&M reach. The industry discharges a significant quantity of pollutants in the aggregate, however, because of the large number of facilities. Thus, the combined effect of discharges from several facilities at a given reach may well result in appreciable risks to human health. Multiple dischargers affecting a single reach were found to be common, based on the sample facility data.

The sample of MP&M facilities on which this analysis is based (910 facilities) represents only approximately 2 percent of MP&M facilities nationwide. This sample was based on basic industry characteristics rather than geographic location. As a result, the sample does not accurately reflect the likelihood of co-occurrence of MP&M facilities on a reach and, therefore, the contribution to in-waterway pollutant concentrations made by multiple facilities. For example, the sample may include three MP&M facilities, all discharging to the same reach. In reality, however, five MP&M facilities might discharge to this reach.

The omission of co-occurrence of discharges from additional facilities does not create a problem in the analysis of incremental cancer risk, because each facility's contribution to total risk can be estimated separately and is assumed be linearly additive. The cancer effects associated with individual facility discharges can be summed over facilities to estimate occurrence of cancer events in the total population. Therefore, the application of sample weights in the cancer analysis accounts for pollutant contributions from facilities co-occurring on MP&M reaches that are not present in the sample of facilities.

This omission does present a problem, however, when analyzing changes in hazard indices and changes in in-waterway pollutant concentrations relative to human health-based AWQC for reaches to which more than one facility discharge. For these reaches, changes in hazard indices and in-waterway pollutant concentrations from reduced pollutant discharges should account for the total discharge of pollutants over the several facilities whose discharges may affect the reach. When facilities whose discharges to the reach have unequal sample weights, however, results from the sample facility analysis cannot be extrapolated to the population simply by multiplying estimated benefit values by the sum of the sample weights of the individual facilities. See Appendix G for an explanation of the sample weighting methodology devised to partially address this problem.

While this weighting methodology does recognize the contributions of facilities with different sample facility weights to aggregate results, it still does not account for the contributions made by co-occurring facilities *not included in the sample*. The omission of the frequency of true multiple discharger effects on aggregate instream concentrations and pollutant exposures understate the benefits.

13.3.2 In-Waterway Concentrations of MP&M Pollutants

Human health benefits are based on the estimated changes in in-waterway concentrations of MP&M pollutants. A variety of factors affect in-waterway concentrations, including flow rates under average and low flow conditions, flow depth, chemistry of the waterway, mixing processes, longitudinal dispersion, flow geometry, suspension of solids, and reaction rates. This analysis takes into account only site-specific variations in flow rates and flow depth. Standard values are used for other inputs to the water quality model, due to lack of data on the reaches affected by sample facility discharges. These standard values may not be accurate for all the sample facility reaches. In addition, the flow characteristics of the sample facility reaches may not be representative of the national distribution of those characteristics. Extrapolating the sample facility benefits to national results based on sample facility weights may therefore introduce distortions. The net effect of these assumptions and extrapolations on the aggregate benefits estimates is uncertain.

13.3.3 Joint Effects of Pollutants

The analyses of human health benefits ignore the potential for joint effects of more than one pollutant. Each pollutant is dealt with in isolation; the individually estimated effects are then added together. As such, the analyses do not account for the possibility that several pollutants may combine to yield more or less adverse effects to human health than indicated by the simple sum of the individual effects. The impact of this limitation on the results of this analysis is unknown.

13.3.4 Background Concentrations of MP&M Pollutants

Background concentrations of MP&M pollutants are not considered in the benefits analysis. Rather, the analysis assumes that MP&M facilities are the only source of each of the regulated pollutants in the waterway. Background contributions, either from other upstream sources or contaminated sediments from previous discharges, are not considered. Even if discharges of these contaminants are reduced or eliminated, sediment contamination and subsequent accumulation of the regulated pollutants in aquatic organisms may continue for years.

Excluding background contributions to in-waterway pollutant concentrations affects the results for non-cancer risk and changes in human health-based AWQC exceedances. In the non-cancer risk analysis, hazard indices are likely to be systematically biased downwards by the omission of exposures to these chemicals from other water-related and non-water-related sources.[12] The net result is understated absolute risks of non-cancer health hazards. Similarly, reductions in human health-based AWQC exceedances calculated for a given MP&M reach are likely to be systematically biased downwards. The analysis is therefore likely to understate the frequency with which in-waterway pollutant concentrations move from values exceeding pollutant specific AWQC to values less than pollutant specific AWQC as a result of the regulation.

13.3.5 Downstream Effects

The analysis of cancer effects from drinking water consumption considered exposures from intakes downstream of the MP&M discharges. EPA, however, did not evaluate cancer risk to recreational and subsistence fishermen fishing downstream reaches, because of resource constraints. In addition, due to differential weighting of sample facility results, it was not possible to evaluate hazard indices indicating non-cancer health hazards or human health-based AWQC excursions in downstream reaches. By omitting these downstream effects, this analysis potentially understates baseline risks that would be reduced by the final option:

- cancer cases (from fish consumption),
- populations exposed to non-cancer risks, and
- waterways with pollutant concentrations exceeding human health-based AWQC.

13.3.6 Exposed Fishing Population

Estimating the exposed fishing populations for specific MP&M reaches requires statistics on county fishing licences. EPA collects these data for every state where the MP&M facilities are located where the state collects these data at the county level. Where fishing license data were not available at the county level, EPA estimated the exposed fishing population based on state fishing license statistics and census data. This approach is likely to understate actual fishing populations. As noted in Section 13.1.1, the *1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* found that 34 percent of the anglers (16 years of age and older) did not have licenses (U.S. Department of the Interior, 1996). In addition, data limitations hamper the estimate of the number of anglers who actually fish a given MP&M reach. Estimating the number of anglers fishing MP&M reaches based on the ratio of MP&M reach length to the total number of MP&M reach miles in the county recognizes the effect of the quantity of competing fishing opportunities on the likelihood of fishing a given reach, but it does not account for the differential quality of fishing opportunities. If water quality in substitute sites is distinctly worse or better, the estimates of the exposed populations are likely to be overstated or understated.

In addition, the number of subsistence anglers was assumed to equal 5 percent of the recreational fishing population. The magnitude of subsistence fishing in the United States or in individual states is not known. As a result, this estimate may understate or overstate the actual number of subsistence anglers.

Finally, to account for the effect of a fish advisory on fishing activity, and therefore on the exposed fishing population, EPA reduced the fishing population at an MP&M reach under a fish advisory by 20 percent. This could either overestimate or underestimate the risk associated with consumption of contaminated fish, because (1) anglers who change locations may simply be switching to other locations where advisories are in place and therefore maintain or increase their current risk, and (2) anglers who continue to fish contaminated waters may change their consumption and preparation habits to reduce the risks from the contaminated fish.

[12] Ideally, the analysis would include not only background concentration and exposure effects from water-related exposures but would also account for exposures to chemicals by other routes including, air exposures including dust inhalation, and food contamination.

13.3.7 Treatment of Cancer Latency

Cancer latency refers to the time between the initial event that leads to cancer (e.g., chemical damage to DNA) and the onset of cancer. Ideally, cancer would be detected at a very early stage, when very few cells are involved. In reality, cancer latency is a very complex issue, and the time to detection varies considerably.

- Latency is related to health, age, immune status, genetics and other characteristics of the individual.
- Latency is also related to the specific carcinogen, the route of exposure, the type of cancer, the technology used for cancer detection, and numerous other factors.
- Environmentally induced cancers may not follow a typical progression pattern; their latency may be unusually shortened.
- Cancers may begin long before they are detected. The exact progress and time of recognition/detection of cancer cannot be predicted, because of the numerous factors involved.
- Variations in timing of cancer detection are partially attributable to the type of cancer involved, the individuals affected, and differences in the medical technology used.
- The fundamental issue is when the damage related to cancer actually begins in an individual and when the continued cell damage stops. Damage to the individual begins when cancer is induced. Once cellular changes begin, the immune system and other body resources are diverted to limiting the carcinogenic process and organ system damage is occurring.

EPA assumed that benefits of avoiding cancer begin to accrue when the initial events leading to cancer cease, even though the benefits may not be clinically measurable until some point in the future. In making this assumption, the Agency considered two factors:

- uncertainty as to how and when exposure changes translate into reduced cancer risk, and
- economic uncertainty associated with the value of avoiding cancer and the timing at which a value of cancer avoidance is recognized.

The monetary valuation of mortality risk from cancer in EPA benefit-cost analyses is based on the VSL. This is derived from a number of revealed-preference studies that estimate the value of avoided premature mortality. The estimates correspond to the value of unforeseen instant death with no significant period of morbidity. The value of an avoided cancer case used in this analysis may therefore be understated, and ultimately the estimated value of the human health benefit of the final regulation may be understated.

13.3.8 Treatment of Cessation Lag

In August 2001, EPA's Science Advisory Board (SAB) recommended that EPA should not assume that a reduction in cancer cases immediately follows a reduction in exposure (U.S.EPA, 2001). The SAB explained that, in fact, there is a lag between the time when exposures are reduced and the time when a reduction in risk occurs, and that "...if the lag between reduction in exposure and reduction in risk is long, there will be fewer cancer fatalities avoided in years immediately following the policy than if the lag were shorter." However, the Agency points out the published studies that attempted to address cessation lag found that after cessation of exposure, cancer risk begins to decline quickly (U.S. EPA, 2001).

The analysis of cancer benefits presented did not account for a cessation lag because the relevant information was not available for all but one (arsenic) MP&M pollutants. Not accounting for cessation lag results in an upper bound estimate of cancer-related benefits (U.S. EPA, 2001).

13.3.9 Use of Mean Individual Exposure Parameters

EPA used mean individual exposure parameters and not the distribution of exposure parameters to estimate hazard indices, cancer risk, and adverse human health effects associated with exposure to lead for the populations affected by MP&M discharges. Because individuals associated with high-end exposure parameter estimates would have higher health risks, EPA's approach is likely to result in underestimation of human health risk reduction from the final MP&M regulation.

13.3.10 Cancer Potency Factors

EPA's estimates of cancer cases were calculated using cancer potency factors that are upper bound estimates of cancer potency, potentially leading to overestimation of cancer risk.

GLOSSARY

ambient water quality criteria (AWQC): AWQC present scientific data and guidance of the environmental effects of pollutants which can be useful to derive regulatory requirements based on considerations of water quality impacts; these criteria are not rules and do not have regulatory impact (U.S. EPA. 1986. Quality Criteria for Water 1986. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC. EPA 440/5-86-001).

marine reach: a specific length of marine coastline.

MP&M reach: a reach to which an MP&M facility discharges.

no observed adverse effect level (NOAEL): exposure level at which there are no statistically or biologically significant differences in the frequency or severity of any effect in the exposed or control populations.

reach: a specific length of river, lake shoreline, or marine coastline.

reference dose (RfD): an estimate of the maximum daily ingestion in that is likely to be without an appreciable risk of deleterious effects during a lifetime.

value of a statistical life saved (VSL): a monetary value of fatalities. A statistical life is saved when the mortality rate of a group of people is reduced sufficiently that one less person will die than would otherwise be the case. One must distinguish between statistical and actual lives. An actual life is saved when the identity of the beneficiary is known before the lifesaving expenditure is made.

waterway: streams, lakes, bays, and estuaries.

willingness-to-pay (WTP): maximum amount of money one would give up to buy some good. (http://www.damagevaluation.com/glossary.htm)

ACRONYMS

AWQC: ambient water quality criteria
NOAEL: no observed adverse effect level
RfD: reference dose
RSEI: Risk Screening Environmental Indicator Model
SDWIS: Safe Drinking Water Information System
VSL: value of a statistical life saved
WTP: willingness-to-pay

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Chapter 14: Lead-Related Benefits

INTRODUCTION

The human health benefits analysis presented in the previous chapter examined both cancer and ***non-cancer health risks*** from exposure to MP&M pollutants. EPA performed a separate analysis of benefits from reduced exposure to lead. The analysis of health effects from exposure to lead is based on ***dose-response functions*** tied to specific ***health endpoints*** to which monetary values can be applied. In this way it differs from the analysis of non-cancer health risk from exposure to other MP&M pollutants. This analysis assessed benefits of reduced lead exposure from consumption of contaminated fish tissue to three population groups: (1) preschool age children, (2) pregnant women, and (3) adult men and women. These lead-related benefits were estimated for the final MP&M regulation, the 433 Upgrade Options, and the Proposed/NODA option.

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EPA estimated benefits to preschool children based on a ***dose-response relationship*** for intelligence quotient (IQ) decrements. The Agency calculated monetary values for avoided neurological and cognitive damages based on the impact of an additional IQ point on an individual's future earnings and the cost of compensatory education for children with learning disabilities. EPA also assessed the incidence of neonatal mortality due to changes in maternal ***blood lead (PbB)*** levels during pregnancy based on ***willingness-to-pay (WTP)*** values for avoiding death. EPA estimated that the final regulation will not yield any benefits to children from reduced exposure to lead.

The health effects in adults that EPA was able to quantify all relate to lead's effect on blood pressure ***(BP)***. Quantified health effects include incidence of hypertension in adult men, initial non-fatal ***coronary heart disease (CHD)***, non-fatal strokes (***cerebrovascular accidents (CBA)*** and ***atherothrombotic brain infarctions (BI)***), and premature mortality. EPA used cost of illness ***(COI)*** estimates (i.e., medical costs and lost work time) to estimate monetary values of reduced incidence of hypertension, initial CHD, and strokes. EPA used COI estimates to estimate monetary values for reduced incidence of hypertension, initial CHD, and strokes. This analysis uses the $6.5 million estimate of the value of a statistical life saved recommended in the *Guidelines for Preparing Economic Analysis* (EPA, 2000a) to estimate monetary value of reduced incidence of premature mortality. EPA estimated that the final rule will achieve no lead-related health benefits among adults.

14.1 OVERVIEW OF LEAD-RELATED HEALTH EFFECTS

The MP&M regulation will reduce lead exposure by reducing the amount of lead discharged to water bodies from MP&M facilities, thereby reducing health and ecological risks. This section provides a brief summary of the human health effects from exposure to lead. Data for this analysis are taken from the Agency for Toxic Substance and Disease Registry's ***(ATSDR)*** Draft Toxicological Profile for Lead (1997) unless otherwise noted. The discussion provided in this section is qualitative and was not used to generate risk estimates.

Lead and lead compounds are toxic and pose threats to human health and well being. The health effects of very high levels of PbB include convulsions, coma, and death from lead toxicity. These effects have been understood for many years. The effects of lower doses of lead are not fully understood, however, and continue to be the subject of intensive scientific investigation (CDC,1991b).

Lead accumulates in the body and is stored in various organ systems. While high level exposures are of immediate concern due to ***acute toxicity***, exposure to small amounts can accumulate over time to harmful levels. Accumulated lead is very persistent, with a ***half-life*** in bone of approximately 27 years.[1] Known or strongly suspected health effects include kidney, stomach, and respiratory cancer, nervous system disorders, hypertension, anemia and blood disorders, gastrointestinal disorders, renal damage, and other effects (ATSDR, 1997; ***CARB***, 1996). Increased mortality from these effects has been observed in studies (ATSDR, 1997).

Many lead-associated adverse health effects are both chronic in nature and relatively common. These effects include but are not limited to hypertension, coronary artery disease, and impaired cognitive function. Specific cases of these conditions are difficult to link to lead exposure because the same adverse health effects or endpoints can arise from a variety of causes. Despite numerous studies conducted by EPA and other institutions, dose-response functions are available only for a handful of health endpoints associated with elevated PbB levels.[2] The available research does not always allow complete economic evaluation, even for quantifiable health effects.

Lead is harmful to any exposed individual, and the effects of lead on children are of particular concern. Children's rapid development rate makes them more susceptible to ***neurobehavioral deficits*** resulting from lead exposure. U.S. EPA identifies three sensitive populations: children under age one, children between the ages one and seven, and adult men and women (U.S. EPA, 1990). New research suggests that children older than seven may also be a hypersensitive population. Recent research on brain development among 10- to 18-year-old children shows unanticipated and substantial growth in brain development, mainly in the early teenage years (Giedd et al., 1999). This analysis does not, however, include this group due to data limitations. Table 14.1 summarizes the quantifiable health effects on children under seven and adult men and women, along with other important, non-quantified, known health effects on these populations.

[1] A half-life of 27 years means that it takes 27 years for the levels measured in bone to decrease by 50 percent.

[2] In a pioneering study, Schwartz et al. quantified a number of health benefits that would result from reducing the lead content of gasoline (U.S. EPA, 1985). EPA extended this work by analyzing lead in drinking water (U.S. EPA, 1986a) and by funding the study of lead in the air (U.S. EPA, 1987).

Table 14.1: Quantified and Unquantified Health Effects of Lead

Population Group	Quantified Health Effect	Unquantified Health Effect
Children ages 0-7	Neonatal mortality due to decreased gestational age and low birth weight caused by maternal exposure to lead Nervous system effects in children younger than 7 years - IQ decrements, cases of IQ less than 70, PbB levels greater than 20 μg/dL	Fetal effects from maternal exposure (including diminished IQ and reduced birth weight) Low IQ (70 <IQ< 84) Permanent brain structure changes Slowed/delayed growth Delinquent and anti-social behavior Metabolic effects, impaired ***heme synthesis***, anemia Impaired hearing Possible cancer - stomach, kidney, respiratory tract Lead effects in children over 7 years
Adult Female ages 45-74	Ages 45-74 Non-fatal CHD Non-fatal stroke Mortality	Non-fatal CHD, non-fatal strokes and mortality for women in other age ranges Other cardiovascular diseases Hypertension Hypertension in pregnant women Reproductive effects - reduced fertility ***Neurobehavioral function*** Gastrointestinal effects - nausea, constipation, loss of appetite Renal effects - chronic ***nephropathy***, gout Possible cancer - stomach, kidney, respiratory tract
Adult Male ages 20 - 74	*For men in specified age ranges:* Ages 20-74 Hypertension Ages 40-75 Non-fatal CHD Mortality Ages 45-74 Non-fatal stroke	Non-fatal CHD, non-fatal strokes and mortality for men in other age ranges Other cardiovascular diseases Reproductive - men: sperm abnormalities Neurobehavioral function Gastrointestinal effects - nausea, constipation, loss of appetite Renal effects - chronic nephropathy, gout Possible cancer - stomach, kidney, respiratory tract

Source: U.S. EPA analysis.

14.1.1 Children Under Age One

Fetal exposure to lead *in utero* from maternal lead intake may result in several adverse health effects, including decreased gestational age, body weight, head circumference, body length, late fetal death, and increased infant mortality (Moore et al., 1982; McMichael et al., 1986; Ward et al., 1987; Dietrich et al., 1987; Bornschein et al., 1989; Bellinger et al., 1991). The Centers for Disease Control ***(CDC)*** estimated that the risk of infant mortality increases by 10^{-4} for each 1 μg/dL increase in maternal PbB level during pregnancy (CDC, 1991b). Neurobehavioral deficits in infants can result from both pre-natal and early post-natal exposure. The metabolic effects described for children in the section below have also been identified in infants. These effects can be quantified based on the dose-response relationship between PbB levels and intelligence quotient (IQ) decrements (Schwartz, 1994).

14.1.2 Children Between the Ages of One and Seven

Elevated PbB levels in children may result in metabolic effects such as impaired heme synthesis, anemia, slowed growth, and cancer (U.S. EPA, 1990). Severe lead poisoning may result in seizures, impaired coordination, recurrent vomiting, coma, and acute lead ***encephalopathy***, a potentially fatal condition (Piomelli et al., 1984). Elevated lead exposure may also induce a number of effects on the human nervous system. These effects include hyperactivity, behavioral and attentional difficulties, delayed mental development, and motor and perceptual skill deficits. The neurobehavioral effects on children can be quantified based on the dose-response relationship for IQ decrements (Shwartz,1993).

14.1.3 Adults

EPA has classified lead as a probable human carcinogen (Group 2b) based on animal toxicological evidence (IRIS, 2002a; see file titled Lead and Compounds (inorganic)). Lead also has been strongly suggested as the causative agent in numerous studies of kidney, stomach, and respiratory cancer in humans. The cancers observed in human studies are usually lethal. A cancer potency factor for lead has not been published by U.S. EPA, however, due to uncertainties associated with human studies. The California Environmental Protection Agency ***(CEPA)*** has also classified lead as a carcinogen and estimated a cancer potency factor of 8.5×10^{-3} per mg/kg/day for exposure to lead and lead compounds (California Air Resource Board [CARB], 1996).[3] Reduced cancer risk associated with reduced exposure to lead can be estimated based on cancer cases avoided (see Section 13.2.1). The Agency did not incorporate cancer effects from exposure to lead in the final rule analysis because these effects appeared very small compared to other adverse health effects from exposure to lead (e.g., neurological damages to children).

Elevated PbB has been linked to elevated BP in adults, especially in men aged 40 to 59 (Pirkle et al., 1985). Elevated BP, itself a health hazard, is also a risk factor for heart attack, stroke (Shurtleff, 1974; McGee and Gordon, 1976; Pooling Project Research Group ***[PPRG]***, 1978), and premature death. Since heart disease and its related diseases are the primary cause of death in the United States, avoiding their exacerbation by minimizing lead exposure can be assumed to have considerable benefits for the affected population. Although elevated BP in women results in the same effects as for men, the general relationships between BP and these health effects differ somewhat across gender (Shurtleff, 1974).

Other known or strongly suspected health endpoints include nervous system disorders in adults, anemia and blood disorders, gastrointestinal disorders, and renal damage (Roels et al., 1976; Factor-Litvak et al., 1993; 1998; and 1999). Finally, data suggest that lead is ***genotoxic*** and may cause chromosomal damage in humans leading to birth defects (Anwar, 1994; Apostoli et al., 2000; Sallmen et al, 2000). Lead may also cause other adverse reproductive effects in women, including increased miscarriage and stillbirth (U.S. EPA 1990). A study of National Health and Nutrition Examination Surveys ***(NHANES)*** II data by Silbergeld et al. suggests that accumulated lead is stored in women's bone tissues and is mobilized back into the blood during the bone demineralization associated with pregnancy, lactation, and osteoporosis (Silbergeld et al., 1988). Many of these effects cannot be quantified due to a lack of information on the dose-effect relationship.

14.2 Health Benefits to Children

The following analysis assesses benefits to children from reduced lead exposure, via reduced consumption of contaminated fish tissue.[4] This analysis uses PbB concentrations as a ***biomarker*** of lead exposure.[5] EPA estimated PbB levels in the population of exposed children to obtain both baseline and post-compliance readings. Changes in those readings yielded estimated benefits from reduced lead exposure in the form of avoided damages. Avoided neurological and cognitive damages are expressed as changes in overall IQ levels, including reduced incidence of extremely low IQ scores (<70, or two standard deviations below the mean), and reduced incidence of PbB levels above 20 µg/dL. The neurological and cognitive damages avoided are then quantified using the value of compensatory education that an individual would otherwise need, and the impact on that individual's future earnings. This analysis does not quantify additional benefit categories, such as the costs of PbB screening and medical treatment. The reduced loss in IQ points, reduced cases of IQ levels below 70 points, and reduced special education costs associated with various PbB levels are likely to be the largest benefit categories. This analysis does not estimate the cost of group homes and other special care facilities.

The analysis of health benefits to children involves the following steps:

- estimate the baseline and post-compliance lead discharges from MP&M facilities;

[3] The cancer potency factors for lead acetate and lead subacetate are 28×10^{-1} and 3.8×10^{-2}, respectively.

[4] This analysis does not consider the beneficial effects due to reduced drinking water exposure. EPA has issued drinking water criteria for lead. This analysis assumes drinking water treatment has already reduced lead content below threshold levels.

[5] PbB concentration is the most common measure of body-lead burden. Other measures of body-lead burden include lead in bones, teeth, and hair.

- estimate lead concentrations in receiving water bodies before and after final effluent guidelines based on lead discharge estimates, effluent flow, characteristics of the receiving POTWs, and characteristics of receiving water bodies;

- estimate the baseline and post-compliance dietary lead intake of children via fish consumption;

- estimate PbB levels of exposed children before and after the final regulation, based on in-stream lead concentrations, bioconcentration factors, and fish consumption rates for children;

- assess changes in health impacts to children from reduced lead exposure, including changes in IQ loss, changes in incidence of IQ<70, and changes in neonatal mortality;

- estimate monetary benefits resulting from reduced adverse health impacts to children; and

- estimate benefits from changes in neonatal mortality from reduced maternal exposure to lead.

Figure 14.1 depicts the above steps.

The following sections summarize the relevant dose-response relationships for children, and discuss data sources used for the dose-response relationships. Each section also includes the methods used to value the changes in health effects based upon dose-response relationships.

14.2.1 PbB Distribution of Exposed Children

This section describes the estimation of changes in PbB distribution of exposed children.

a. Estimating lead concentrations in the receiving water bodies

Estimating health risks associated with lead exposure from fish consumption requires calculating in-waterway lead concentrations. The method and formulas for this calculation were identical to those described for the analysis of cancer effects for the fish consumption pathway (see Chapter 13 on Human Health Benefits and the Environmental Assessment in Appendix I for details.)[6]

b. Estimating PbB levels in exposed children

This analysis considers children that are born today and live in recreational and subsistence fishermen households. The analysis considers a continuous exposure pattern for children from birth through the seventh birthday. Exposure, health effects, and benefits are calculated separately for children living in recreational and subsistence fishing households. This analysis relies on EPA's ***Integrated Exposure, Uptake, and Biokinetics (IEUBK)*** Model for Lead in Children (IEUBK version 0.99d, March 8, 1994).

❖ ***Description of the IEUBK model***

The IEUBK model uses exposure, uptake, and biokinetic response information to estimate the PbB level distribution for a population of children receiving similar exposures. The estimated distribution may be used to predict the probability of elevated PbB levels in children exposed to a specific combination of environmental-lead levels. The model addresses four components of environmental risk assessment:

- the multimedia nature of exposure to lead;

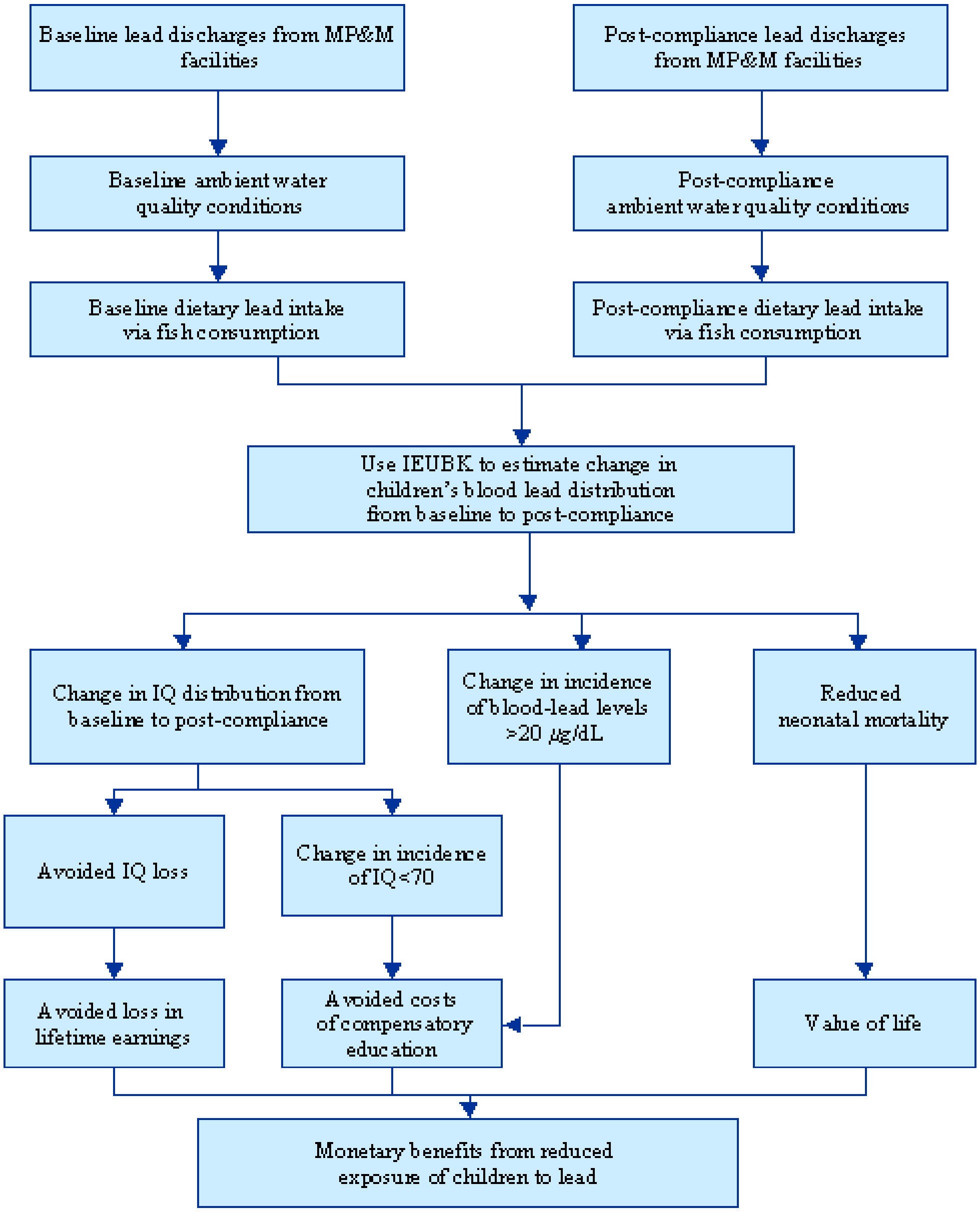
- the differential ***bioavailability*** of various sources of lead;

- the ***pharmacokinetics*** of internal distribution of lead to bone, blood, and other tissues; and

- inter-individual variability in PbB levels.

[6] The water quality model used for the Ohio case study is discussed in Appendix H.

Figure 14.1 Assessing Benefits to Children from Reduced Lead Discharges from MP&M Facilities



Source: U.S. EPA analysis.

The model uses estimated or measured lead concentrations in fish tissues and other media, such as soil, dust, air, and water to estimate a continuous exposure pattern for children from birth through the seventh birthday (U.S. EPA, 1995). The model then estimates a distribution of PbB levels for a population of children receiving similar exposures by predicting its ***geometric mean (GM)***. The inter-individual and biological variability in PbB levels of children exposed to similar environmental lead levels is represented by the ***geometric standard deviation (GSD)***. This analysis uses an empirical estimate of the variability in PbB concentrations, a GSD of 1.6, estimated from residential community PbB studies (U.S. EPA, 1995). This estimate is applied for predictions of the national distribution of PbB concentrations.

The model has three distinct functional components that work together in a series:

- exposure,
- uptake, and
- ***biokinetics*** response.

Each model component is a set of complex equations and parameters. The Technical Support Document (U.S. EPA, 1995) provides the scientific basis of the parameters and equations used in the model, while the Guidance Manual (U.S. EPA, 1994) includes a detailed description of the exposure pathways, absorption mechanism, biokinetic compartments, and associated comparted transfers of lead.

❖ *Inputs to the IEUBK model*

The IEUBK model uses three sets of parameters:

- exposure parameters estimate the amount of environmental lead taken into the body, through breathing or ingestion;
- uptake parameters estimate the amount of lead absorbed from environmental sources;
- biokinetic parameters characterize the transfer of lead between compartments of the body (e.g., between blood and bone) and elimination of lead from the body.

The IEUBK model allows the user to input values for most exposure and uptake parameters. The biokinetic parameter values cannot be altered. When exposure and uptake values are not specified, the IEUBK model provides default values. Table 14.2 summarizes the key parameter values used in this analysis and indicates whether a value is an IEUBK default value or has been specified by EPA.[7]

1. Exposure parameters include exposure rates and exposure concentrations:

    - Exposure rates: Children in recreational fishing households are assumed to consume 6.03 grams of fish per day. Children living in subsistence households are assumed to consume 30.33 grams of fish per day. These fish consumption rates are based on uncooked fish weights. The fish consumption rate for children in recreational fishing households is calculated as a weighted average based on West et al. (U.S. EPA, 1997a) for children ages 1-5 (5.63 grams of fish per day) and children ages 6-10 (7.94 grams of fish per day). For children of subsistence fishing households, the fish consumption rate is calculated as a weighted average based on Columbia River Intertribal Fish Commission (CRITFC, 1994) estimates for children under age 5 (19.6 grams of fish per day) and the Continuing Survey of Foods by Individuals (U.S. EPA, 2002b) for children ages 3-5 (40.31 grams of fish per day) and ages 6-10 (61.49 grams of fish per day).

    - Exposure concentrations: EPA used estimated in-stream concentrations of lead to calculate lead concentration of the fish consumption exposure pathway. The Agency used 1996 monitoring data (U.S. EPA, 1996b) on lead concentrations in air and the Housing and Urban Development National Survey (HUD, 1995) for data on lead concentrations in dust and soil to characterize lead exposure concentrations for these exposure pathways.[8] This

[7] A complete list of IEUBK default parameters is presented in Appendix L.

[8] EPA found that the typical PbB level distribution predicted in the IEUBK Model for Lead in Children based on the default values for air, dust, soil, and drinking water lead concentrations did not correspond to the most recent national population PbB distribution (NHANES III, Phase 2, 1994). Therefore, the Agency used more recent data to characterize the background exposure to environmental

analysis uses median concentration values for these three pathways as inputs to the IEUBK to characterize background exposure to environmental lead. EPA used the IEUBK default value for lead concentration in drinking water that takes into account contributions of lead from plumbing. Because of past use of lead in plumbing, lead concentrations in tap water are likely to be above the current water quality standard for lead in drinking water.

2. Uptake of ingested lead: Lead bioavailability varies across the chemical forms in which lead can exist. Many factors complicate the estimation of bioavailability, including nutritional status and timing of meals relative to lead intake. The Agency used the default media-specific bioavailabilities in the IEUBK model for this analysis.

3. Biokinetic parameters: The data on which these parameter values are based originate from a variety of sources, including available clinical data (U.S. EPA, 1995). These parameters cannot be changed by the user.

lead. Median values from recent monitoring data allowed the Agency to match the IEUBK-predicted PbB distribution to the NHANES-derived distribution.

Table 14.2: Selected List of Parameters Used in the IEUBK Model				
Variable		**Value**	**IEUBK Default**	**Data Source**
Exposure Rates	Fish: Recreational	6.03 g/day	No	The fish consumption rate for children in recreational fishing households is calculated as a weighted average based on West et al. (U.S. EPA, 1997a) for children ages 1-5 (5.63 g/day) and children ages 6-10 (7.94 g/day). The fish consumption rate for children in subsistence fishing households is calculated as a weighted average based on Columbia River Intertribal Fish Commission (CRITFC, 1994) estimates for children under age 5 (19.6 g/day) and the Continuing Survey of Foods by Individuals (U.S. EPA, 2002b) for children ages 3-5 (40.31 g/day) and ages 6-10 (61.49 g/day).
	Fish: Subsistence	30.33 g/day	No	
	Fresh Fruit	38.481 g/day 0-11 months 169.000 g/day 12-23 months 63.166 g/day 24-35 months 61.672 g/day 36-47 months 61.848 g/day 48-59 months 67.907 g/day 60-71 months 80.024 g/day 72-84 months	Yes	Values taken from Pennington, J. A. T. (1983) *Revision of the total diet study food list and diets*. Journal of American Dietetic Association 82(2): 166-173
	Fresh Vegetables	56.84 g/day 0-11 months 106.50 g/day 12-23 months 155.75 g/day 24-35 months 157.34 g/day 36-47 months 158.93 g/day 48-59 months 172.50 g/day 60-71 months 199.65 g/day 72-84 months	Yes	Values taken from Pennington, J. A. T. (1983) *Revision of the total diet study food list and diets*. Journal of American Dietetic Association 82(2): 166-173
	Meat (Including fish and game)	29.551 g/day 0-11 months 87.477 g/day 12-23 months 95.700 g/day 24-35 months 101.570 g/day 36-47 months 107.441 g/day 48-59 months 111.948 g/day 60-71 months 120.961 g/day 72-84 months	Yes	Values taken from Pennington, J. A. T. (1983) *Revision of the total diet study food list and diets*. Journal of American Dietetic Association 82(2): 166-173
	Air (Time spent outdoors)	1 hrs/day 0-11 months 2 hrs/day 12-23 months 3 hrs/day 24-35 months 4 hrs/day 36-47 months 4 hrs/day 48-59 months 4 hrs/day 60-71 months 4 hrs/day 72-84 months	Yes	Based on values reported in (1) U.S. Environmental Protection Agency (U.S. EPA), *Review of the National Ambient Air Quality Standards for Lead: Assessment of Scientific and Technical Information.* OAQPS Staff Paper, Air Quality Management Division, Research Triangle Park, NC (EPA 1989c), and (2) *Report of the Clean Air Scientific Advisory Committee on Its Review of the OAQPS Lead Staff Paper.* EPA-SAB-CASAC-90-002 (EPA 1990a)

Table 14.2: Selected List of Parameters Used in the IEUBK Model

Variable		Value	IEUBK Default	Data Source
	Water (Daily amount of water consumed)	0.20 L/day 0-11 months 0.50 L/day 12-23 months 0.52 L/day 24-35 months 0.53 L/day 36-47 months 0.55 L/day 48-59 months 0.58 L/day 60-71 months 0.59 L/day 72-84 months	Yes	*Exposure Factors Handbook*. U.S. EPA Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-89/043 (1989b)
	Soil (Combined soil and dust consumption)	0.085 g/day 0-11months 0.135 g/day 12-23 months 0.135 g/day 24-35 months 0.135 g/day 36-47 months 0.100 g/day 48-59 months 0.090 g/day 60-71 months 0.085 g/day 72-84 months	Yes	Based on value reported in *Review of the National Ambient Air Quality Standards for Lead: Assessment of Scientific and Technical Information*. OAQPS Staff Paper, Air Quality Management Division, Research Triangle Park, NC (1989c)
Exposure Concentrations	Fish Tissue	site-specific	No	Estimated based on predicted lead concentration in receiving reaches and bioconcentration factor for lead (49 L/Kg)
	Outdoor Air	0.03 μg/m^3	No	Median value for 1996 from EPA's AIRS (Aerometric Information Retrieval System) air monitoring data (U.S. EPA, 1996b)
	Indoor Air	30% of Outdoor Air	Yes	Based on value reported in *Review of the National Ambient Air Quality Standards for Lead: Assessment of Scientific and Technical Information*. OAQPS Staff Paper, Air Quality Management Division, Research Triangle Park, NC (1989c)
	Water	4.0 μg/L	Yes	Analysis of data from American Water Works Service Co. in *Marcus, A.H. (1989) Distribution of lead in tap water*. Parts I and II. Report to the U.S. EPA Office of Drinking Water/Office of Toxic Substances, from Battelle Memorial Institute under Contract 68-D8-0115.
	Soil	61.78 μg/g	No	Median values from the Housing and Urban Development National Survey (U.S. Department of Housing and Urban Development, 1995)
	Dust	187.11 μg/g	No	
Food Lead Intake	Fresh Fruit	0.039 μg/day 0-11 months 0.196 μg/day 12-23 months 0.175 μg/day 24-35 months 0.175 μg/day 36-47 months 0.179 μg/day 48-59 months 0.203 μg/day 60-71 months 0.251 μg/day 72-84 months	Yes	Based on data provided by FDA in *Air Quality Criteria for Lead Vol I-IV*. U.S. EPA Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA 600/8-83-028a-d (1986b)

Table 14.2: Selected List of Parameters Used in the IEUBK Model

Variable		Value	IEUBK Default	Data Source
	Fresh Vegetables	0.148 µg/day 0-11 months 0.269 µg/day 12-23 months 0.475 µg/day 24-35 months 0.466 µg/day 36-47 months 0.456 µg/day 48-59 months 0.492 µg/day 60-71 months 0.563 µg/day 72-84 months	Yes	Based on data provided by FDA in *Air Quality Criteria for Lead Vol I-IV*. U.S. EPA Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA 600/8-83-028a-d (1986b)
	Meat (No fish or game meat)	0.226 µg/day 0-11 months 0.630 µg/day 12-23 months 0.811 µg/day 24-35 months 0.871 µg/day 36-47 months 0.931 µg/day 48-59 months 1.008 µg/day 60-71 months 1.161 µg/day 72-84 months	Yes	Based on data provided by FDA in *Air Quality Criteria for Lead Vol I-IV*. U.S. EPA Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA 600/8-83-028a-d (1986b)
	Other Foods (No fish or game meat)	3.578 µg/day 0-11 months 3.506 µg/day 12-23 months 3.990 µg/day 24-35 months 3.765 µg/day 36-47 months 3.545 µg/day 48-59 months 3.784 µg/day 60-71 months 4.215 µg/day 72-84 months	Yes	Based on data provided by FDA in *Air Quality Criteria for Lead Vol I-IV*. U.S. EPA Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA 600/8-83-028a-d (1986b)
Lead Absorption Factor	Food	0.5	Yes	Based on values reported in the *Review of the National Ambient Air Quality Standards for Lead: Exposure Analysis Methodology and Validation*; Report No. EPA-450/2-89/011; U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC (1989d)
	Air	32%	Yes	
	Water	0.5	Yes	
	Soil	0.3	Yes	
	Dust	0.3	Yes	
Biokinetic Parameters		IEUBK default values and equations were used for all biokinetic parameters (these cannot be changed by the user). The complete list of IEUBK biokinetic parameters is listed in Appendix L and in the *Technical Support Document: Parameters and Equations Used in the IEUBK Model for Lead in Children*. U.S. EPA, EPA 540-R-94-040, (1995)		
Age Fish Introduced in Infant Diet		9 months	N/A	Literature on dietary guidelines for children from various childcare organizations, including the *National Network for Child Care*

Source: U.S. EPA analysis.

c. Estimating changes in the PbB level in exposed children from reduced MP&M discharges

EPA used the IEUBK model in this analysis to estimate the effect of lead-contaminated fish consumption on children's PbB concentrations. The Agency first calculated lead concentration in fish tissue corresponding to each reach affected by MP&M discharges to provide inputs to the IEUBK model. The model uses the specified fish tissue concentrations in conjunction with fish ingestion rates and bioavailability factors to determine the dose of lead absorbed by the body. This dose is then used to predict the GM PbB concentration for children associated with each reach affected by lead discharges from the MP&M facilities.

EPA used the IEUBK model to predict the baseline and post-compliance PbB distributions for children that consume fish from reaches affected by lead discharges from MP&M facilities. The difference between the estimated baseline and post-compliance PbB distribution is the basis for the analysis of benefits to children from the MP&M regulation.

14.2.2 Relationship Between PbB Levels and IQ

A dose-response relationship between PbB and IQ decrements determined by Schwartz (1994) suggests that a decrease of 0.25 IQ points can be expected for every 1 µg/dL increase in PbB (Schwartz, 1994). The ***p-value*** (< 0.0001) indicates that this relationship is highly significant.

EPA multiplied the 0.25 IQ points lost per µg/dL increase in PbB by the average increase in PbB level for children and by the number of exposed children to obtain the total change in number of IQ points for the population. The average PbB level modeled in this analysis is a GM, not the ***arithmetic mean*** used by Schwartz (1993). To adjust for this difference, equation 14.1 uses a ratio between the arithmetic mean and the GM of a ***lognormally-distributed random variable***. The ratio between the expected value (mean) of the distribution and the GM is 1.117 for the assumed GSD of children's PbB levels (1.6).

The total avoided loss of IQ points for each group is estimated as:

$$(AVOIDED\ \ LOSS\ \ of\ \ IQ\ \ POINTS)_k = \Delta GM_k \times .25 \times (Pop_k)\ /7 \qquad (14.1)$$

where:

$(Pop)_k$ = the number of children (up to age seven) in anglers' families in the vicinity of a given MP&M reach; and
GM_k = the GM of the PbB distribution in the population of children.

As shown in equation 14.1, the population of children up to age seven is divided by seven to avoid double-counting. The IEUBK model calculates the GM of the PbB distribution in the population of children born today, assuming a continuous exposure pattern for children from birth through the seventh birthday. Assuming that children are evenly distributed by age, this division adjusts this equation to apply only to children age 0-1. Dividing by seven undercounts overall benefits. Children from age 1 to 7 are not accounted for in the base year of the analysis, although they are presumably affected by the lead exposure, because the IEUBK model assumes a continuous exposure pattern for children from birth through the seventh birthday.

14.2.3 Value of Children's Intelligence

Available economic research provides little empirical data on society's overall WTP to avoid a decrease in an infant's IQ. This analysis uses research that monetizes a subset of effects associated with decreased IQ. These effects represent only some components of society's WTP to avoid IQ decreases, and underestimate society's WTP when employed alone. For the purpose of this analysis, these effects are the only ones available at this time to approximate the WTP to avoid IQ decrements.

Recent studies provide concrete evidence of long-term effects from childhood lead exposure (Schwartz, 1994). This analysis assumes a permanent loss of IQ points based on PbB levels estimated for children up to age seven, and considers two consequences of this IQ decrement:

- the decreased present value of the infant's expected lifetime earnings, and
- the increased educational resources expended for an infant who becomes mentally handicapped or needs compensatory education as a consequence of lead exposure.

a. Estimating the effect of IQ on earnings

Reduced IQ has direct and indirect effects on earnings. This analysis models the overall impact from a one-point reduction in IQ as the sum of these direct and indirect effects on lifetime earnings. EPA used the most recent estimates of the effects of IQ on earnings based on Salkever (1995).[9] Salkever provided updated estimates of the direct and indirect effects of IQ loss on earnings, using the most recent available data set, the National Longitudinal Survey of Youth ***(NLSY)***. Salkever used ***regression analysis*** techniques to estimate direct and indirect effects of IQ on earnings. Three different relationships are estimated separately for male and female respondents:

- a ***least-squares regression*** of highest grade on IQ test scores;
- a ***probit regression*** of a 0-1 indicator of positive earnings on highest grade and IQ test scores;
- a least-squares regression, for persons with positive earnings, of the logarithm of earnings on highest grade and IQ test scores.

Other variables were included in each regression to control for effects of family background (parents' education and income), the age of the respondent, ethnic group, and residence location (urban U.S., non-urban U.S., south versus non-south).

Based on the regression results, Salkever estimated the effects of IQ on earnings as the sum of direct and indirect effects:

- The direct effect is the sum of effects of IQ test scores on employment and earnings for employed persons, holding the years of schooling constant.
- The indirect effect is the sum of effects of IQ test scores on years of schooling attained, and the subsequent effect of years of schooling on the probability of employment and on earnings for employed persons.

The analysis found that percentage effects of lead exposure are greater for females than for males. The total estimated effect of the loss of an IQ point on earnings, based on the Salkever study, is an earnings reduction of 1.93 percent for men and 3.22 percent for women. The total effect of the loss of an IQ point on earnings also includes non-IQ effects on schooling (e.g., behavioral problems).

b. Valuing foregone earnings

EPA monetized IQ loss effects by combining the percent earnings loss estimate with an estimate of the present value of expected lifetime earnings. EPA used the 1992 data on money income for the U.S. population (U.S. Department of Commerce, 1993) to calculate the mean present value of lifetime earnings of a person born today. The data included earnings for employed persons and employment rates as a function of educational attainment, age, and gender. The following assumptions were used to calculate the mean present value of lifetime earnings of a person born today:

- The distribution of earnings for employed persons and labor force participation rates remains constant over time.
- A person earns income from age 18 through age 67.
- Real wages grow one percent per year.
- Future earnings are discounted at a three percent annual rate.

The money income data (U.S. Department of Commerce, 1993) form the best available basis for projecting lifetime earnings, but involve some uncertainties. Labor force participation rates of women, the elderly, and other groups will likely continue to change. Currently, men tend to earn more than women due to higher wage rates and higher labor force participation. Expected lifetime earnings increase with education for both men and women. Real earnings of women will probably continue to rise relative to real earnings of men. Educational attainment has risen over time and may continue to rise. Unpredictable

[9] EPA did not incorporate earlier studies of the effects of IQ on earnings in this analysis because the Salkever study is more complete in capturing the various pathways through which IQ affects earnings, such as the indirect effect of IQ on earnings via its effect on educational attainment. Also, other studies are much older. The IQ/earning effect is likely to be higher during the high tech boom in the last decade.

fluctuations in the economy's growth rate will probably affect labor force participation rates and real wage growth for all groups. Medical advances that increase life expectancy will probably increase lifetime earnings.

Although earnings data alone form an incomplete measure of an individual's value to society, this analysis does not account for those individuals who do not participate in the labor force at all throughout their working years and whose productive services are not measured by wage rates. The largest group in this population are those who remain at home doing housework and child rearing. Volunteer work also contributes significantly to social welfare, and volunteerism rates tend to increase with educational attainment and income. Assuming that the ***opportunity cost*** of non-wage-compensated work equals the average wage earned by persons of the same sex, age, and education, the average lifetime earnings estimates would be significantly higher. Recalculating the tables using full employment rates for all age, sex, and education groups would provide higher lifetime earnings estimates. To be conservative, this analysis considered only the value of lost wages and does not include the opportunity cost of non-wage-compensated work.

The adjusted value of expected lifetime earnings equals the present value for an individual entering the labor force at age 18 and working until age 67. Given a three percent social discount rate, the other assumptions mentioned, and current survival probabilities, the present value of lifetime earnings of a person born today in the U.S. would be $448,957 (2001$).[10]

c. Valuing costs of education

The increase in lifetime earnings from additional education equals the gross return on education. The cost of education is subtracted from the gross return to obtain the net increase in earnings from additional education. The cost of education has two components: the direct cost of the education, and the opportunity cost of lost income during the education. The ***marginal cost*** of education used in this analysis was assumed to be $8,898 (2001$) per year. This figure was derived from the U.S. Department of Education's reported ($6,961) average per-student annual expenditure (current plus capital expenditures) in public primary and secondary schools in 1995-96 (U.S. Department of Education, 1998).[11] EPA adjusted this value to 2001 dollars based on CPI for education.

Salkever’s study found the estimated effect of IQ on educational attainment to be 0.1007 years per IQ point. The estimated cost of an additional 0.1007 years of education per IQ point is $896 (i.e., 0.1007 × $8,898). This marginal cost was discounted to the time the exposure and damage is modeled to occur (age zero) because this cost is incurred after the completion of formal education. The average level of educational attainment in the population over age 25 is 12.9 years (U.S. Department of Education, 1993). The marginal educational cost was therefore assumed to occur at age 19, resulting in a discounted present value cost of $511 (2001$).

The other component of the cost of education is the opportunity cost of lost income while in school. Income loss is frequently cited as a major factor in the decision to terminate education, and must be subtracted from the gross returns to education. An estimate of the lost income was derived assuming that people in school are employed part-time but that people out of school are employed full-time. The opportunity cost of lost income is the difference between full-time and part-time earnings. The value of lost income associated with being in school an additional 0.1007 years is $746 (2001$) discounted to age zero.

d. Estimating the total effect of IQ on earnings

Combining the value of lifetime earnings ($448,957) with the estimate of percent wage loss per IQ point yielded $10,675 per IQ point. Subtracting the education and opportunity costs reduced this value to $9,419 per IQ point (2001$).

14.2.4 Value of Additional Educational Resources

Children with IQs less than 70 and whose PbB is greater than 20 µg/dL will require additional educational resources including an educational program tailored to the mentally handicapped. Some children whose PbB is greater than 20 µg/dL will need additional instruction while attending school later in life. The following sections describe approaches used to quantify the number of children with IQs less than 70 and to estimate increased educational costs resulting from lead exposure.

[10] Assuming a seven percent social discount rate, the present value of lifetime earnings of a person born today in the U.S. would be $101,247 (2001$). Appendix M presents a sensitivity analysis with respect to the value of an IQ point.

[11] In comparison, the average annual cost of tuition, fees, room, and board for a four-year public undergraduate institution was $8,655 (2001$) for the year 2000-2001 (U.S. Department of Education, 2001).

a. Children with IQs less than 70

❖ *Quantifying the number of children with IQs less than 70*

Increases in the mean PbB levels of children results in an increased incidence of children with very low IQ scores. IQ scores are normalized to have a mean of 100 and a standard deviation of 15. An IQ score of 70 is two standard deviations below the mean, and is generally regarded as the point below which children require significant special compensatory education tailored to the mentally handicapped.

The relationship presented here for estimating changes in the incidence of IQs less than 70 used the most current IQ point decrement function provided by Schwartz (1993). It assumed that, for a baseline children's PbB distribution (defined by GM and GSD), the population also has a normalized IQ point distribution with a mean of 100 and a standard deviation of 15. The proportion of the population expected to have IQs less than 70 was determined from the standard **normal distribution** function for this baseline condition:

$$P(IQ<70) = \Phi(z) \tag{14.2}$$

where:

P(IQ <70)	=	probability of IQ scores less than 70
z	=	standard normal variate (i.e., the number of standard deviations); computed for an IQ score of 70, with mean IQ score of 100 and standard deviation of 15 as:

$$z = \frac{70-100}{15} = -2 \tag{14.3}$$

Φ(z)	=	standard normal distribution function:

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-\frac{u^2}{2}} du \tag{14.4}$$

The integral in the standard normal distribution function does not have a closed form solution. Values for Φ(z) are usually obtained using software with basic statistical functions or from tables typically provided in statistics texts. The solution for Φ(z) where z = -2 is 0.02275. That is, for the normalized IQ score distribution with a mean of 100 and standard deviation of 15, approximately 2.3 percent of children are expected to have IQ scores below 70.

EPA made two key assumptions to relate changes in the proportion of children with IQ scores below 70 to changes in population mean PbB levels:

1. The mean IQ score will change as a result of changes in the mean PbB level as:

$$\triangle \textit{ Mean IQ} = -0.25 \times \triangle \textit{ Mean PbB} \tag{14.5}$$

   where:

△ *Mean IQ*	=	the change in the mean IQ score between the baseline and post-compliance scenarios, and
△ *Mean PbB*	=	the change in the mean PbB level between the two scenarios.

   This relationship relies on Schwartz' estimate (1993) of a decrease of 0.25 IQ points for each µg/dL increase in PbB. The mean PbB level referred to here is the arithmetic mean (or expected value) for the distribution, obtained as described previously from the GM and GSD.

2. The standard deviation for the IQ distribution is 15 for both the baseline and the post-compliance scenario.

Using these assumptions, EPA determined the change in the probability of children having IQ less than 70 for a given change in mean PbB from:

$$\Delta P(IQ<70) = \Phi(z_{Bl}) - \Phi(z_{Pc}) = \Phi(z_{Bl}) - 0.02275 \tag{14.6}$$

where:

$\Phi(z_{Bl})$ = baseline standard normal distribution function, and
$\Phi(z_{Pc})$ = post-compliance standard normal distribution function.

$$z_{Bl} = \frac{70 - (100 + 0.25 \times \Delta MeanPbB)}{15} \tag{14.7}$$

EPA then converted a given change in the mean PbB level between the baseline and post-compliance scenarios into a measure of IQ. The procedure above yielded an estimate of the percent of the population with IQs less than 70. EPA multiplied this percent by the population of exposed children to estimate the increased incidence of children with low IQs. As in the IQ point loss equation, EPA applied the results of this function to children age 0-7 and divided by seven to avoid double counting. (See discussion under equation 14.1.)

This procedure quantified only the change in the number of children who pass below the 70 point IQ threshold. EPA quantified other changes in children's IQ using the IQ point loss function (Equation 14.1) described previously. Treating these two endpoints additively does not result in double counting, because the value associated with the IQ point loss function is the change in individual lifetime earnings, while the value associated with IQs less than 70 is the increased educational costs for the individual, as discussed below.

❖ ***Valuing educational costs***

EPA estimated the number of avoided cases of children with IQs less than 70. Compensatory education expenses will no longer be incurred for these cases. Kakalik et al. (1981), using data from a study prepared for the Department of Education's Office of Special Education Programs, estimated part-time special education costs for children who remained in regular classrooms at $3,064 extra per child per year in 1978. Adjusting for changes in the ***GDP price deflator*** yielded an estimate of $6,959 per child in 2001 dollars. EPA used the incremental estimate of the cost of part-time special education to estimate the annual cost per child needing special education as a result of lead impacts on mental development. EPA assumed that compensatory education begins at age seven and continues through age 18 (grades one through twelve). ***Discounting*** future expenses at a rate of three percent yielded an expected present value cost of approximately $58,012 per child (2001$). This discounting underestimates the cost because Kakalik et al. measured the increased cost to educate children attending regular school rather than a special education program. The costs of attending a special education program are likely to be much higher than those associated with regular schooling. In addition, some compensatory education programs begin earlier than at age seven. For example, some states, such as Connecticut and Rhode Island, offer Head Start programs to disadvantaged children beginning at age three.

b. Children with PbB levels greater than 20 μg/dL

❖ ***Quantifying the number of children with PbB levels greater than 20 μg/dL***

EPA obtained the percentage of children with PbB levels greater than 20 μg/dL directly from the estimated distribution of PbB levels for a given location (IEUBK). EPA then multiplied this percentage by the number of exposed children in the vicinity of a given MP&M reach to estimate the number of children with PbB levels greater than 20 μg/dL.[12]

❖ ***Estimating and valuing compensatory education for children with PbB levels greater than 20 μg/dL***

EPA assumed that 20 percent of the children with PbB levels greater than 20 μg/dL would require and receive compensatory education for three years. After this time, no further educational expenditures are incurred by those children. These

[12] See Section 13.1.1 for detail on estimating the affected population. The percentage of children in the affected population is estimated based on the Census data.

assumptions are conservative. Many studies show adverse cognitive effects of PbB levels at 15 µg/dL (CDC, 1991b). Some studies of the persistence of cognitive effects indicate that the effects often last longer than three years.

The Kakalik et al. (1981) estimate of part-time special education costs for children who remained in regular classrooms can be used to estimate the cost of compensatory education for children suffering low-level cognitive damage. As indicated above, the part-time special education cost per child is $6,959 per year in 2001 dollars. The Agency assumes that compensatory education starts at age 7 and continues for 3 years. Discounting future costs at a rate of 3 percent annually to account for the age at which costs are incurred (i.e., age 7 through 9) yields a present value estimate of $16,485 in 2001 dollars.

14.2.5 Changes in Neonatal Mortality

a. Quantifying the relationship between maternal PbB levels and neonatal mortality

U.S. EPA (1990) cites a number of studies linking fetal exposure to lead (via *in utero* exposure from maternal lead intake) to several adverse health effects. These effects include decreased gestational age (i.e., premature birth), reduced birth weight, late fetal death, and increases in infant mortality.

The CDC (CDC, 1991a) developed a method to estimate changes in infant mortality due to changes in maternal PbB levels during pregnancy. The analysis linked the following two relationships:

- gestational age as a function of maternal PbB (Dietrich et al., 1987), and
- infant mortality as a function of gestational age. This is performed using data from the Linked Birth and Infant Death Record Project from the National Center for Health Statistics (CDC, 1991a).

Combining the two relationships provided a decreased risk of infant mortality of 10^{-4} (or 0.0001) for each 1 µg/dL decrease in maternal PbB level during pregnancy. EPA used this relationship for its analysis of maternal PbB levels and neonatal mortality.

b. Valuing changes in neonatal mortality

This analysis used the estimated WTP for avoiding a mortality event to estimate the monetary benefit associated with reducing risks of neonatal mortality. This analysis uses the $6.5 million (2001$) estimate of the value of a statistical life saved recommended in the *Guidelines for Preparing Economic Analysis* (EPA, 2000a). For detail on valuing reduced mortality risks see Section 13.2.1.

14.3 Adult Health Benefits

Lead exposure has been shown to have adverse effects on the health of adults as well as children. The quantified adult health effects included in the benefits analysis all relate to lead's effects on BP.[13] The estimated relationships between these health effects and lead exposure differ between men and women. Quantified health effects include increased incidence of hypertension (estimated for males only), initial CHD, strokes (initial CBA and BI), and premature mortality. This analysis does not include other health effects associated with elevated BP, and other adult health effects of lead including neurobehavioral and possible cancer effects.

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[13] Citing laboratory studies with rodents, U.S. EPA (1990) also presents evidence of the genotoxicity and/or carcinogenicity of lead compounds. The animal toxicological evidence suggests that human cancer effects are possible, but dose-response relationships are not currently available.

Estimating adult health benefits from reduced exposure to lead requires analytic steps similar to those used in estimating children's health benefits. These steps are:

- estimate in-stream lead concentrations in the reaches affected by MP&M discharges;
- estimate baseline and post-compliance adult dietary lead intake via fish consumption. The analysis of adult health benefits from reduced exposure to lead via contaminated fish uses the results from water quality modeling efforts described in Appendix I;
- estimate changes in the PbB level distribution in the affected adult population;
- estimate changes in health status in the affected population of adult men, and the monetary value of health benefits from reduced lead discharges from MP&M facilities; and
- estimate changes in health status in the affected population of adult women, and the monetary value of health benefits from reduced lead discharges from MP&M facilities.

Figure 14.2 depicts the above steps. Table 14.3 summarizes per-case costs of lead-related illnesses.

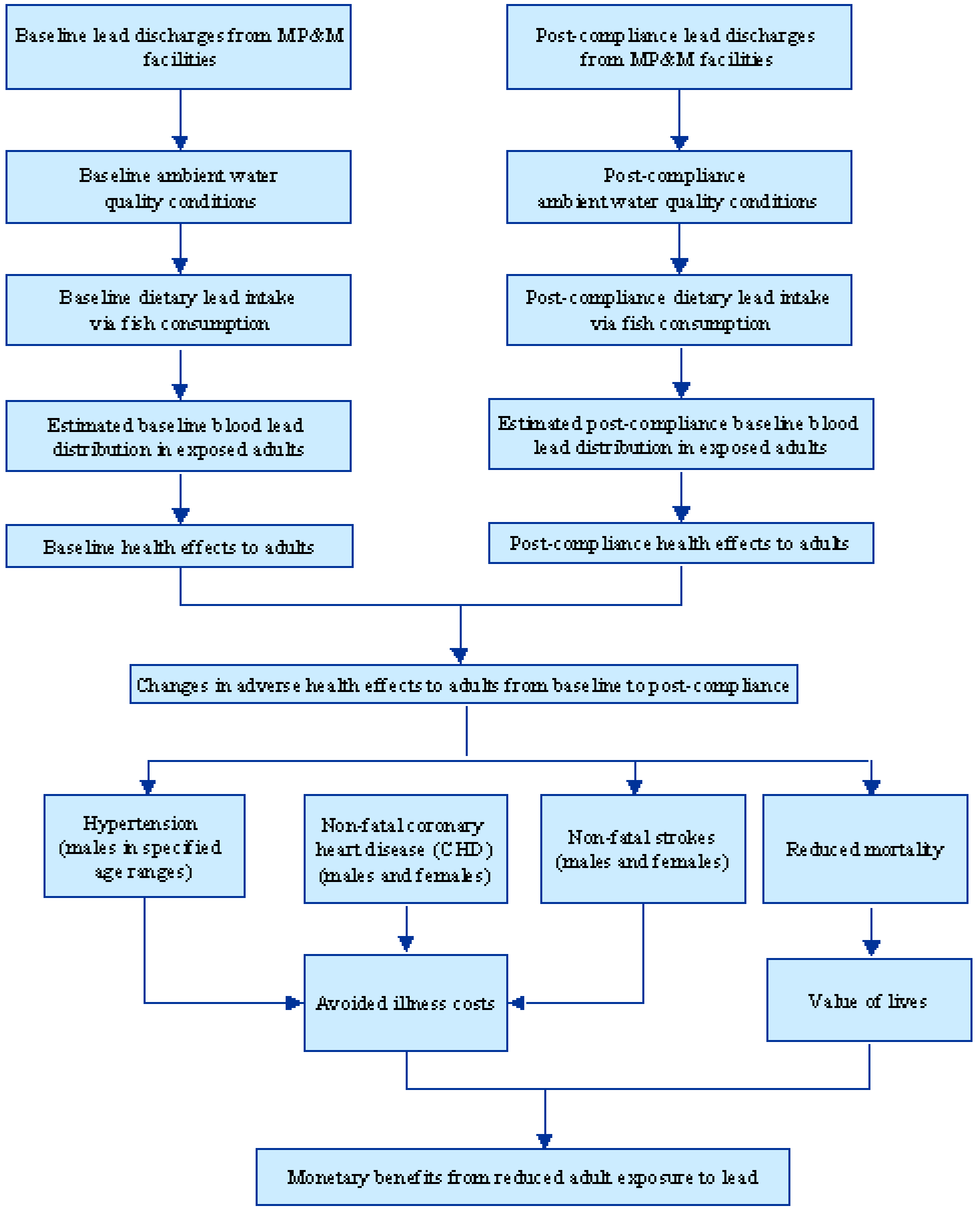
Table 14.3: Per-Case Costs of Lead-Related Illnesses

Illness	Gender	Cost per Case (2001$)	Cost Description
Hypertension[a]	Male	$1,141	The cost estimates were derived by taking Krupnick et al.'s (1989) average annual per-person costs of hypertension. Value adjusted to 2001$ using the CPI for Medical Care.
	Female	$1,141	
CHD[a, b]	Male	$76,347	The costs were estimated (Wittels et al., 1990) for three CHDs (acute myocardial infarction, uncomplicated ***angina pectoris***, and unstable angina pectoris) for 5 years post-diagnosis using a three percent discount rate. The probability of medical service was multiplied by the estimated price of the service and the average cost for the three CHD types. Since the effect of elevated PbB on CHD incidence rates is beyond the scope of this analysis, weighting factors were not used to account for the different probabilities of contracting the three types of CHD. Value adjusted to 2001$ using the CPI for Medical Care.
	Female	$76,347	
Stroke[a]	Male	$335,135	The cost estimates (Taylor et al., 1996) represent the expected lifetime cost of a stroke for males and females age 45-74, including the present discounted value of the stream of medical expenditures and the stream of lost earnings. Note that the study used a five percent discount rate. EPA did not adjust this value to reflect a 3 percent discount rate used elsewhere in this analysis. Values adjusted to 2001$ using the CPI for Medical Care.
	Female	$251,351	
Low Birth Weight[c]	Female	$89,503	The cost estimate was extrapolated from direct costs for LBW taken from Lewitt et al., using a three percent discount rate (Lewitt et al., 1995). The value includes medical, special education, and grade repetition costs. Value adjusted to 2001$ using the CPI for Medical Care.
Death -- Any Illness[d]	Male	$6.5 Million	Value taken from U.S. EPA's Guidelines for Preparing Economic Analysis (2000a). The value is the central estimate recommended in the document based on a range of estimates available from studies measuring the value of a statistical life. Value adjusted to 2001$ using the CPI for All Items.
	Female	$6.5 Million	

[a] *Costs were taken from U.S. EPA, 1997b.*
[b] *Extends methodology in U.S. EPA, 1997b to discount medical costs over a 5 year period.*
[c] *Note that this analysis does not estimate occurrence of low birth weight cases, due to data limitations. Cost was taken from U.S. EPA, 1999.*
[d] *Value taken from U.S. EPA, 2000a.*

Source: U.S. EPA analysis.; U.S. EPA 1997b; U.S. EPA 1999, U.S. EPA 2000a.

Figure 14.2 Assessing Benefits to Adults from Reduced Lead Discharges from MP&M Facilities



Source: U.S. EPA analysis.

14.3.1 Estimating Changes in Adult PbB Distribution Levels

a. Estimating values of PbB concentrations in exposed adults

EPA adapted the methodology described in the *Interim Approach to Assessing Risks Associated with Adult Exposure to Lead in Soil* (hereafter, Interim Guidance) to estimate changes in the distribution of PbB levels in exposed adults from reduced MP&M discharges (U.S. EPA, 1996a). The methodology presented in the Interim Guidance used a simplified representation of lead biokinetics to predict ***quasi-steady state*** PbB concentrations among adults who have relatively steady patterns of exposures to lead. This methodology is recommended by the ***Technical Review Workgroup (TRW)*** to assess the effects of ingesting lead-contaminated soil on PbB levels of women of childbearing age, to derive ***risk-based remediation goals (RBRG)*** protective of the developing fetus in exposed adult women.[14] The Interim Guidance describes the basic algorithms to be used in the analysis and provides a set of default parameters that can be used in cases where site-specific data are not available. The TRW points out that this methodology is an interim approach recommended for use pending further development and evaluation of integrated exposure biokinetic models for adults.

The dose-response relationship recommended in the Interim Guidance for exposures to lead-contaminated soil can be modified to analyze PbB levels in recreational and subsistence anglers exposed to lead-contaminated fish tissue. In both cases, the exposure pathways involve ingestion. The Interim Guidance differs from this analysis mainly in the medium containing lead (soil versus fish tissue). Substituting ingestion of lead in fish for ingestion of lead in soil yields the following equation:

$$PbB_{adult,\ central} = PbB_{adult,0} + \frac{PbW \times BCF \times IN_F \times AF_F \times BKSF \times EF \times CF}{AT} \tag{14.8}$$

where:

$PbB_{adult,\ central}$	=	***central tendency estimate*** of PbB concentrations (µg/dL) in adults exposed to lead in fish at a concentration of PbW;
$PbB_{adult,\ 0}$	=	typical PbB concentration (µg/dL) in adults in the absence of exposures via fish consumption;
PbW	=	in-stream lead concentrations (µg/L);
BCF	=	bioconcentration factor of lead in fish tissue (L/kg);
IN_F	=	average daily fish consumption (g/day);
AF_F	=	***absolute gastrointestinal absorption fraction*** for ingested lead in fish tissue (dimensionless);
BKSF	=	biokinetic slope factor relating (quasi-steady state) increases in typical adult PbB concentrations to average daily lead uptake (µg/dL PbB increase per mg/day lead uptake);
EF	=	exposure frequency for ingestion of contaminated fish (days of exposure during the averaging period); may be taken as days per year for continuing, long-term exposure;
CF	=	conversion factor (10^{-3} kg/g); and
AT	=	averaging time, the total period during which fish consumption may occur; 365 days/year for continuing long-term exposure.

Equation 14.8 is recommended for females aged 17 to 45 (U.S. EPA, 1996a). Studies of adult males, however, provided many of the parameters used in the Interim Guidance. For example, the biokinetic slope factor (BKSF) relating increase in typical adult blood concentrations to average daily lead uptake was developed on data reported by Pocock et al (1983). These data characterize the relationship between tap water lead concentrations and blood lead concentrations for a sample of adult males.[15] Thus, EPA judged that this model can be applicable to all adults. Table 14.4 summarizes values for the model parameters.

[14] EPA's TRW for lead began considering methodologies to evaluate nonresidential adult exposure to lead in 1994. A TRW committee on adult lead risk assessment formed in January 1996 to develop a generic methodology that could be adapted for use in site-specific assessments of adult health risks.

[15] For detail, see p.A-10, *Recommendations of the Technical Review Workgroup for Lead to Assessing Risks Associated with Adult Exposure to Lead in Soil* (U.S. EPA, 1996a).

Table 14.4: Summary of Parameter Values for Estimating PbB Levels in Adults

Parameter	Unit	Value		Comment [a]
$PbB_{adult,0}$	µg/dL	4.55-3.45		Male adult PbB levels based on NHANES III Phase 2 (U.S. EPA, 1991-1994). Female adult PbB levels based on NHANES III Phase 2 (U.S. EPA, 1996a).
BKSF	µg/dL per µg/day	0.4		Based on analysis of Pocock et al. (1983) and Sherlock et al. (1984) data.
INF	g/day	17.5	142.4	Daily fish consumption; lower value (on left) for recreational anglers and higher value (on right) for subsistence anglers. Fish consumption rates for adults are taken from the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (EPA, 2000b). Both these rates, 142.4 g/day for adult subsistence anglers and 17.5g/day for adult recreational anglers, are used for the specific sub-population that they represent. EPA was not able to break these rates down by gender or age group for use in this analysis.
EF	day/yr	365		Days per year for continual long-term exposure.
BCF	L/kg	49		Bioconcentration factor of lead in fish tissue.
AF_F	dimen-sionless	0.03		Absolute gastrointestinal absorption fraction for ingested lead in fish tissue. Based on Maddaloni (1998).

[a] For detailed information on the sources of the parameters and uncertainties associated with their use, see U.S. EPA, 1996a.

Source: U.S. EPA analysis.

❖ *Typical adult PbB concentrations at baseline*

Previous research suggests males have a higher background PbB level (U.S. EPA, 1996a). This analysis uses population-specific typical concentrations to account for differences in background lead exposure between genders and between two socioeconomic subgroups considered in the analysis (i.e., recreational and subsistence fishermen). EPA used data for adult males and females from NHANES III to characterize the baseline distribution of PbB concentrations in the relevant sub-populations for each MP&M reach and affected population (NHANESIII, 1991-1994). The baseline PbB distribution scenario reflects site-specific population characteristics because baseline PbB levels differ across ethnic, income, and urban status groups.

❖ *Bioavailability of lead from fish tissue*

To identify lead bioavailability in fish tissue, EPA reviewed lead absorption data from various materials reported in the lead toxicity summary document: *Draft Toxicological Profile for Lead* (ATSDR, 1997). EPA also reviewed *Measurement of Soil-Borne Lead Bioavailability in Human Adults, and Its Application to Biokinetic Modeling* (Maddaloni, 1998) and consulted with the study author (March, 2000). Numerous studies have found that lead ingested with food is absorbed at a significantly lower rate than lead ingested after fasting. The Interim Approach reports this dynamic and notes that "the bioavailability of ingested soluble lead in adults varies from less than 10 percent when ingested with a meal to between 60 and 80 percent when ingested after a fast" (U.S. EPA, 1996a). TRW uses a 20 percent lead bioavailability factor for soil. This factor is based on lead consumption interspersed with and between meals throughout the day, and is therefore likely to overestimate PbB levels in adults exposed to lead-contaminated fish. In the absence of data on lead incorporated into food, however, EPA considered this to be the most appropriate data to use in estimating absorption.

In the most recent study reviewed for this analysis (Maddaloni, 1998), non-fasted subjects showed a mean percent absorption of 2.52 with a range of 0.2 to 5.2 percent and a confidence value of 0.66. The male and female study subjects had normal clinical chemistry parameters and were between 21 and 40 years of age. The study used soil as the dosing vehicle. Other studies have used water as the dosing vehicle, but soil is considered to be more similar to fish consumption.

EPA selected an absorption value of 3 percent for lead ingested in fish tissue, based on Maddaloni's results. The value of 3 percent provides a reasonable estimate for most adults. This analysis does not address individuals who may have higher lead absorption, or are at elevated risk due to lead exposure. These individuals include pregnant women, who have higher calcium requirements (and are therefore more likely to be calcium-deficient), people with poor nutritional status (including iron and calcium deficiencies), and individuals with other metabolic disorders. By evaluating subsistence and recreational anglers at proposal and for final rule options with lead benefits, the analysis is already focusing on sub-populations at higher risk than the average population. To maintain an approach that represents likely exposures, intakes, and risks, EPA chose not to consider individuals at unusually high risk within an already-high risk sub-population.

14.3.2 Male Health Benefits

This section describes the health effects of reduced lead exposure that this analysis has quantified for men; the next section presents a similar discussion for women.

a. Hypertension

❖ ***Quantifying the relationship between PbB levels and hypertension***

Studies have linked elevated PbB to elevated BP in adult males, especially men aged 40 to 59 (Pirkle et al., 1985). Further studies have demonstrated a dose-response relationship for hypertension (defined as diastolic BP above 90 mm Hg for this model) in males aged 20 to 74 (Schwartz, 1988). This relationship is:

$$\Delta Pr(HYP) = \frac{1}{1 + e^{2.744 - .793*(\ln PbB_1)}} - \frac{1}{1 + e^{2.744 - 0.793*(\ln PbB_2)}} \quad (14.9)$$

where:

ΔPr(HYP)	=	the change in the probability of hypertension,
e	=	base of the natural logarithm (2.76)
PbB_1	=	PbB level in the baseline scenario, and
PbB_2	=	PbB level in the post-compliance scenario.

❖ ***Valuing reductions in hypertension***

The best measure of the social costs of hypertension, society's WTP to avoid the condition, cannot be quantified without basic research that is well beyond the scope of this project. Ideally, the measure would include all the medical costs associated with treating hypertension, the individual's WTP to avoid the worry that hypertension could lead to a stroke or CHD, and the individual's WTP to avoid the behavioral changes required to reduce the probability that hypertension leads to a stroke or CHD.

This analysis used recent research results to quantify two benefit category components: medical costs and lost work time. Krupnick and Cropper (1989) estimated the medical costs of hypertension, using data from the National Medical Care Expenditure Survey. Medical costs include expenditures for physician care, drugs, and hospitalization. In addition, hypertensives have more bed disability days and work-loss days than non-hypertensives of comparable age and sex. Krupnick and Cropper estimated the increase in work-loss days at 0.8 per year. Valuing this estimate at the estimated mean daily wage rate and adjusting the costs to 2001 dollars yields an estimate of the annual cost of each case of hypertension of $1,141.

The benefits estimate in this analysis likely underestimates the true social benefit of avoiding a case of hypertension for several reasons:

- It does not include a measure of the value of pain, suffering, and stress associated with hypertension.
- It does not value the direct costs (out-of-pocket expenses) of diet and behavior modification (e.g., salt-free diets, etc.). These costs, which are typical for severe modifications, are likely to be significant.
- This analysis does not address the loss of satisfaction associated with the diet and behavior modifications.
- This analysis does not include the value of avoiding side effects associated with the medication for hypertension, which include drowsiness, nausea, vomiting, anemia, impotence, cancer, and depression.
- The analysis does not include the effects of the disease on family members.

b. Changes in CHD

❖ *Quantifying the relationship between PbB and BP*

EPA quantified the effect of changes in PbB levels on changes in BP to predict the probability of both hypertension and other cardiovascular illnesses, such as CHD, strokes, and premature mortality. Several cardiovascular illnesses include PbB as a risk factor (Shurtleff, 1974; McGee and Gordon, 1976; PPRG, 1978). Based on the results of a meta-analysis of several studies, Schwartz (1992) estimated a relationship between a change in BP associated with a decrease in PbB from 10 µg/dL to 5 µg/dL. The following equation uses the coefficient reported by Schwartz to relate BP to PbB for men:

$$\Delta DBP_{men} = 1.4 \times \ln\left(\frac{PbB_1}{PbB_2}\right) \tag{14.10}$$

where:

ΔDBP_{men} = the change in men's diastolic BP expected from a change in PbB;
PbB_1 = PbB level in the baseline scenario (in µg/dL); and
PbB_2 = PbB level in the post-compliance scenario (in µg/dL).

EPA used this PbB to BP relationship to estimate the incidence of initial CHD, strokes (BI and initial CBA), and premature mortality in men.

❖ *Quantifying the relationship between BP and CHD*

This analysis used estimated BP changes to predict the increased probability of initial CHD and stroke occurrence (U.S. EPA, 1987). Increased BP also increases the probability of CHD and stroke recurrence, but EPA did not quantify these relationships in this analysis. An equation with different coefficients for each of three age groups can predict first-time CHD events in men. A 1978 study by the PPRG supplied information for men between ages 40 and 59. PPRG used a **multivariate** model (controlling for smoking and serum cholesterol) relating the probability of CHD to BP. The model used data from five different epidemiological studies. The equation for the change in 10-year probability of a first-time occurrence of CHD related to an increase in BP is:

$$\Delta Pr(CHD_{40-59}) = \frac{1}{1 + e^{4.996 - 0.030365 * DBP_1}} - \frac{1}{1 + e^{4.996 - 0.030365 * DBP_2}} \tag{14.11}$$

where:

$\Delta Pr(CHD_{40-59})$ = the change in 10-year probability of an occurrence of a CHD event for men between ages 40 and 59;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 40 to 59 is 81.8 and 80.0, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

Information presented in Shurtleff (1974) helped define the relationship between BP and first-time CHD in older men. This study used data from the Framingham Study (McGee and Gordon, 1976) to estimate univariate relationships between BP and a variety of health effects, by sex and for three age ranges: 45 to 54, 55 to 64, and 65 to 74 years. The study performed single composite analyses for ages 45 to 74 for each sex. For every equation, t-statistics on the BP variable are significant at the 99th percent confidence interval. EPA predicted first-time CHD related to an increase in BP for men aged 60 to 64 from the following equation:

$$\Delta Pr(CHD_{60-64}) = \frac{1}{1 + e^{4.996 - 0.030365 * DBP_1}} - \frac{1}{1 + e^{4.996 - 0.030365 * DBP_2}} \tag{14.12}$$

where:

$\Delta Pr(CHD_{60-64})$ = the change in 2-year probability of occurrence of a CHD event for men aged 60 to 64;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 60 to 64 is 79.5 and 77.8, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

The following equation uses data from Shurtleff (1974) to predict the probability of first-time CHD related to an increase in BP for men aged 65 to 74:

$$\Delta Pr(CHD_{65-74}) = \frac{1}{1 + e^{4.90723 - 0.02031 * DBP_1}} - \frac{1}{1 + e^{4.90723 - 0.02031 * DBP_2}} \quad (14.13)$$

where:

$\Delta Pr(CHD_{65\text{-}74})$	=	the change in 2-year probability of occurrence of a CHD event for men aged 65 to 74;
DBP_1	=	mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 65 to 74 is 79.5 and 76.4, respectively; and
DBP_2	=	mean diastolic BP in the post-compliance scenario.

EPA used the above equations to estimate the number of CHD events avoided in a given year due to water quality improvements from reduced MP&M lead discharges. The resulting CHD incidence estimates include both fatal and non-fatal events. Only the non-fatal CHD events are considered here because mortality benefits are estimated independently in this analysis (see Section 14.3.2.d, below). Shurtleff (1974) reported that two-thirds of all CHD events were non-fatal. This factor was therefore applied to the estimate of avoided CHD events due to reductions in PbB and BP for each age category.

❖ ***Valuing reductions in CHD events***

EPA first estimated the number of CHD events avoided each year by multiplying the number of exposed recreational and subsistence anglers in the relevant age group by the change in annual probability of a CHD event. Changes in annual probability of CHD events for different age groups are calculated by dividing the change in probability over ten- and two-year periods by the relevant number of years.

EPA then used the central tendency estimate of the COI associated with pollution-related CHD to estimate the benefits of avoiding an initial CHD event. The cost estimates (Wittels et al., 1990) represent the weighted medical costs of three separate CHDs (acute myocardial infarction, uncomplicated angina pectoris, unstable angina pectoris), experienced within five years of diagnosis. EPA estimated the costs by multiplying the probability of a medical test or treatment (within five years of the initial CHD event) by the estimated price of the test or treatment.[16] The estimated cost for acute myocardial infarction was then reduced by 23%, which represents the proportion of cases that go unrecognized by the patient and therefore do not result in any medical costs (based on Hartunian et al., 1981). EPA used a three percent discount rate to calculate the present value of these costs. EPA then calculated the final cost estimate by taking the simple average of the three CHD types. The central tendency estimate of the COI associated with a case of pollution-related CHD is about $76,347 (2001$).

This estimate likely underestimates the full COI because it does not include lost earnings. It likely underestimates total WTP to avoid CHD to an even greater extent because it does not include WTP to avoid the pain and suffering associated with the CHD event.

This analysis combined the value of reducing CHD events with the value of reducing hypertension, even though these conditions often occur together. The two values represent different costs associated with the conditions. The valuation for hypertension includes hypertension-associated work day loss and medical costs. CHD valuation is based on the medical costs for treatment associated with the CHD itself. EPA estimated these two values separately and added them together.

c. Changes in initial CBA and initial BI

❖ ***Quantifying the relationship between BP and first-time stroke***

Strokes include two types of health events: initial CBA and initial BI. The risk of CBA has been quantified for the male population between 45 and 74 years old (Shurtleff, 1974). For initial CBA, the equation is:

[16] EPA obtained costs from Appendix G of the *Benefits and Costs of the Clean Air Act: 1970 to 1990*, prepared for U.S. Congress by U.S. EPA, Office of Air and Radiation and Office of Policy, Planning, and Evaluation, 1997b.

$$\Delta Pr(CBA_{men}) = \frac{1}{1 + e^{8.58889 - 0.04066 * DBP_1}} - \frac{1}{1 + e^{8.58889 - 0.04066 * DBP_2}} \tag{14.14}$$

where:

$\Delta Pr(CBA_{men})$ = the change in 2-year probability of CBA in men;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 45 to 74 is 81.1 and 78.8, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

For initial BI, the equation is (Pirkle et al., 1985):

$$\Delta Pr(BI_{men}) = \frac{1}{1 + e^{9.9516 - 0.04840 * DBP_1}} - \frac{1}{1 + e^{9.9516 - 0.04840 * DBP_2}} \tag{14.15}$$

where:

$\Delta Pr(BI_{men})$ = the change in 2-year probability of brain infarction in men;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 45 to 74 is 81.1 and 78.8, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

Similarly to CHD events, this analysis estimates only non-fatal strokes to avoid double-counting with premature mortality. Shurtleff reported that 70 percent of strokes were non-fatal. EPA applied this factor to the estimates of both CBA and BI to ensure that the estimate of avoided CBA and BI events included only non-fatal events (Shurtleff, 1974).

❖ ***Valuing reductions in strokes***

Similarly to CHD events, EPA first calculates the number of avoided strokes per year and then uses the estimated lifetime cost of a stroke to value reductions in strokes. Taylor et al. estimated the lifetime cost of stroke, including the present value (in 1990 dollars) of the stream of medical expenditures and the present discounted value of the stream of lost earnings, using a five percent discount rate (Taylor et al., 1996). The estimated expected lifetime cost of a non-fatal stroke for males aged 45 to 74 is 335,135 (2001$).[17]

d. Changes in premature mortality

❖ ***Quantifying the relationship between BP and premature mortality***

It is well established that elevated BP increases the probability of premature death. There are, however, several underlying conditions that cause elevated BP (e.g., cholesterol level). U.S. EPA (1987) used population mean values for serum cholesterol and smoking to reduce results from a 12-year follow-up of men aged 40 to 54 in the Framingham Study (McGee and Gordon, 1976) to an equation with one explanatory variable (DBP):

$$\Delta Pr(MORT_{40-54}) = \frac{1}{1 + e^{5.3158 - 0.03516 * DBP_1}} - \frac{1}{1 + e^{5.3158 - 0.03516 * DBP_2}} \tag{14.16}$$

where:

$\Delta Pr(MORT_{40-54})$ = the change in 12-year probability of death for men aged 40 to 54;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 40 to 54 is 81.9 and 79.9, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

[17] EPA obtained cost from Appendix G of the *Benefits and Costs of the Clean Air Act: 1970 to 1990*, prepared for U.S. Congress by U.S. EPA, Office of Air and Radiation and Office of Policy, Planning, and Evaluation, 1997b.

This analysis used information from Shurtleff (1974) to estimate the probability of premature death in men older than 54 years. The present analysis estimates a two-year probability based on the Shurtleff study's two-year follow-up period. EPA predicted mortality for men aged 55 to 64 years old using the following equation:

$$\Delta Pr(MORT_{55-64}) = \frac{1}{1 + e^{4.89528 - 0.01866 * DBP_1}} - \frac{1}{1 + e^{4.89528 - 0.01866 * DBP_2}} \qquad (14.17)$$

where:

- $\Delta Pr(MORT_{55-64})$ = the change in two-year probability of death in men aged 55 to 64;
- DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 55 to 64 is 80.6 and 79.0, respectively; and
- DBP_2 = mean diastolic BP in the post-compliance scenario.

Using data from Shurtleff (1974), EPA predicted premature mortality for men aged 65 to 74 using the following equation:

$$\Delta Pr(MORT_{65-74}) = \frac{1}{1 + e^{3.05723 - 0.00547 * DBP_1}} - \frac{1}{1 + e^{3.05723 - 0.00547 * DBP_2}} \qquad (14.18)$$

where:

- $\Delta Pr(MORT_{65-74})$ = the change in two-year probability of death in men aged 65 to 74;
- DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for subsistence and recreational fishermen aged 65 to 74 is 79.5 and 76.4, respectively; and
- DBP_2 = mean diastolic BP in the post-compliance scenario.

❖ ***Valuing reductions in premature mortality***

Similarly to health outcomes discussed in the preceding sections, EPA first estimated changes in annual probability of premature mortality for men in different age groups. The Agency then calculated avoided premature death cases by multiplying the estimated change in annual probability of premature mortality by the relevant population. This analysis uses the $6.5 million (2001$) estimate of the value of a statistical life saved recommended in the *Guidelines for Preparing Economic Analysis* (EPA, 2000a). This value is based on WTP to avoid the risk of death.

The values of avoiding CHD, BA, and BI events are all based on COI estimates associated with a non-fatal health event. On the other hand, the value of the change in premature mortality is based on the value of avoiding a health event that does end in death. Thus, these two endpoints are additive.

14.3.3 Female Health Benefits

Recently expanded analysis of data from NHANES II by Schwartz indicates a significant association between PbB and BP in women (Schwartz, 1990). Another study, by Rabinowitz et al. (1987), found a small but demonstrable association between maternal PbB, pregnancy hypertension, and BP at time of delivery.

a. Relationship between BP and PbB

Although women are at risk for lead-induced hypertension, no dose-response function for hypertension in women is available at this time. Therefore, the Agency did not quantify changes in risk for lead-induced hypertension in women for this analysis. This analysis used an adjusted dose-response function for a change in BP associated with a decrease in PbB in men (Equation 14.10) to estimate lead-induced changes in blood pressure in women. Equation 14.19 is used to provide input values for the analyses discussed in the following sections.

A review of ten published studies examined the effect of lead exposure on the BP of women, relative to the effect on men (Schwartz, 1992). All of the reviewed studies included data for men; some included data for women. Schwartz used a concordance procedure that combined data from each study to predict the decrease in diastolic BP associated with a decrease from 10 µg/dL to 5 µg/dL PbB (Schwartz, 1992). The results suggest that when PbB is decreased, women experience a BP change that is 60 percent of the change seen in men. Equation (14.10) can be rewritten for women as:

$$\Delta DBP_{women} = (0.6 \times 1.4) \times \ln\left(\frac{PbB_1}{PbB_2}\right) \tag{14.19}$$

where:

ΔDBP_{women} = the change in women's diastolic BP expected from a change in PbB;
PbB_1 = PbB level in the baseline scenario; and
PbB_2 = PbB level in the post-compliance scenario.

b. Changes in CHD

❖ *Quantifying the relationship between BP and CHD*

Elevated BP in women results in the same effects as for men (CHD, two types of stroke, and premature death). However, the general relationships between BP and these health effects are not identical to the dose-response functions estimated for men. All relationships presented here have been estimated for women aged 45 to 74 years old using information from Shurtleff (1974). EPA estimated first-time CHD related to an increase in BP in women using the following equation:

$$\Delta Pr(CHD_{women}) = \frac{1}{1 + e^{6.9401 - 0.03072 * DBP_1}} - \frac{1}{1 + e^{6.9401 - 0.03072 * DBP_2}} \tag{14.20}$$

where:

$\Delta Pr(CHD_{women})$ = change in 2-year probability of occurrence of CHD event for women aged 45-74;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for women in subsistence and recreational households aged 45 to 74 is 76.5 and 74.8, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

EPA estimated non-fatal CHD events by assuming that two-thirds of all estimated CHD events are not fatal (Shurtleff, 1974).

❖ *Valuing reductions in CHD events*

The Agency first calculated the number of avoided CHD events for women using Equation 14.20. EPA assumed that values of reducing CHD events for women equal those calculated for men (above): $76,347 (2001$) per CHD event.

c. Changes in BI and initial CBA

❖ *Quantifying the relationship between BP and first-time stroke*

EPA predicted the relationship between BP and initial CBA for women using the following equation:

$$\Delta Pr(CBA_{women}) = \frac{1}{1 + e^{9.07737 - 0.04287 * DBP_1}} - \frac{1}{1 + e^{9.07737 - 0.04287 * DBP_2}} \tag{14.21}$$

where:

$\Delta Pr(CBA_{women})$ = change in two-year probability of cerebrovascular accident in women aged 45 to 74;
DBP_1 = mean diastolic BP in the baseline scenario; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

The following equation illustrates the relationship between BI and initial BI in women:

$$\Delta Pr(BI_{women}) = \frac{1}{1 + e^{10.6716 - 0.0544 * DBP_1}} - \frac{1}{1 + e^{10.6716 - 0.0544 * DBP_2}} \tag{14.22}$$

where:

$\Delta Pr(BI_{women})$ = change in 2-year probability of brain infarction in women aged 45 to 74;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for women in subsistence and recreational households aged 45 to 74 is 76.5 and 74.8, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

EPA multiplied the predicted incidences of avoided BI and CBA by 70 percent to estimate only non-fatal strokes (Shurtleff, 1974).

❖ ***Valuing reductions in strokes***

EPA calculated the value of avoiding an initial CBA or an initial BI for women in the same way as for men (see above). EPA predicted lead-related stroke for women in the United States between the ages of 45 and 74, of whom 38.2 percent are aged 45 to 54 and the remaining 61.8 percent are aged 55-74. Using the gender- and age-specific values in Taylor et al. (1996), EPA estimated the average value of avoiding a stroke among women aged 45 to 74 to be about $251,351 (2001$).

d. Changes in premature mortality

❖ ***Quantifying the relationship between BP and premature mortality***

The following equation estimates the risk of premature mortality in women (Shurtleff, 1974):

$$\Delta Pr(MORT_{women}) = \frac{1}{1 + e^{5.40374 - 0.01511 * DBP_1}} - \frac{1}{1 + e^{5.40374 - 0.01511 * DBP_2}} \qquad (14.23)$$

where:

$\Delta Pr(MORT_{women})$ = the change in two-year probability of death for women aged 45 to 74;
DBP_1 = mean diastolic BP in the baseline scenario; based on the Phase 2 NHANES III, mean diastolic BP for women in subsistence and recreational households aged 45 to 74 is 76.5 and 74.8, respectively; and
DBP_2 = mean diastolic BP in the post-compliance scenario.

❖ ***Valuing reductions in premature mortality***

EPA predicted changes in lead-related premature mortality for women in the same way as for men (see above). EPA assumed the value of reducing premature mortality in women to be equal to that estimated for all premature mortality, $6.5 million (2001$) per incident (see Section 13.2.1).

14.4 Lead-Related Benefit Results

This section describes the estimated benefits of reduced lead exposure from consumption of fish in three populations: (1) preschool age children, (2) pregnant women, and (3) adult men and women. Benefit estimates for pregnant women appear with those for preschool age children, because the beneficiaries in this category are children under the age of one who suffer *in utero* fetal lead exposure from maternal lead intake during pregnancy. EPA estimated that the final regulation will yield no benefits to children or adults from reduced exposure to lead. Alternative regulatory options considered by EPA were estimated to yield benefits from reduced exposure to lead. The following discussion reviews the estimated benefits from these alternative options.

14.4.1 Preschool Age Children Lead-Related Benefit Results

EPA analyzed the monetary value of health benefits to children from reduced lead exposure in four categories:

- reduced neo-natal mortality,
- avoided IQ loss,
- reduced incidence of IQ below 70, and
- reduced incidence of PbB levels above 20 µg/dL.

From this analysis, EPA estimated that the final rule will yield no lead-related benefits to children.

Other regulatory options considered by EPA were found to yield lead-related benefits to children. Table 14.5 summarizes lead-related benefits estimated for the 433 Upgrade Options. EPA estimated that the Directs + 413 to 433 Upgrade Option and the Directs + All to 433 Upgrade Option would reduce 0.15 and 0.17 cases of neonatal mortality, and avoid the loss of 32 and 36 IQ points, respectively. The Directs + 413 to 433 Upgrade Option and the Directs + All to 433 Upgrade Option would result in $1.3 and $1.5 million (2001$) in annual lead-related benefits for children, respectively.

Table 14.5: National Annual Benefits from Reduced Lead in Children (2001$) — 433 Upgrade Options[a]

Category	Directs + 413 to 433 Upgrade		Directs + All to 433 Upgrade	
	Reduced Cases or IQ Points	Benefit Value (2001$)	Reduced Cases or IQ Points	Benefit Value (2001$)
Neonatal mortality	0.15	$995,630	0.17	$1,109,294
Avoided IQ Loss	31.99	$301,323	36.19	$340,845
Reduced IQ < 70	0.11	$6,637	0.13	$7,501
Reduced PbB > 20 µg/L	0.00	$0	0.00	$0
Total Benefits		$1,303,590		$1,457,640

[a] Based on the Traditional Extrapolation.

Source: U.S. EPA analysis.

Table 14.6 summarizes lead-related benefits estimated for the Proposed/NODA Option. EPA estimated that the Proposed/NODA Option would reduce 1.60 cases of neonatal mortality and avoid the loss of 1,078 IQ points. Annual lead-related benefits for children equal $20.8 million (2001$) under the Proposed/NODA Option, which substantially exceeds estimated lead-related benefits for children under the two 433 Upgrade Options.

Table 14.6: National Annual Benefits from Reduced Lead in Children (2001$) — Proposed/NODA Option[a]

Category	Reduced Cases or IQ Points	Benefit Value (2001$)
Neonatal mortality	1.60	$10,417,781
Avoided IQ Loss	1,078.38	$10,157,286
Reduced IQ < 70	3.72	$216,007
Reduced PbB > 20 µg/L	0.00	$0
Total Benefits		$20,791,073

[a] Based on the Traditional Extrapolation.

Source: U.S. EPA analysis.

The results from the estimated lead-related benefits for children are conservative, because this analysis omits other lead-related impacts, such as the cost of group homes and other special care facilities. Table 14.1 presents other omitted benefits categories. Section 14.5 discusses uncertainty and limitations inherent in this analysis.

14.4.2 Adult Lead-Related Benefit Results

As discussed previously, EPA quantified only the lead-related health effects in adults that relate to lead's effect on BP. These health effects include increased incidence of hypertension, initial non-fatal CHD, non-fatal stokes (CBA and BI), and premature mortality. EPA used COI estimates (i.e., medical costs and lost work time) to estimate monetary values for reduced incidence of hypertension, initial CHD, and strokes. EPA based monetary values for changes in risk of premature mortality on estimates of the value of a statistical life saved. The results are conservative estimates, because this analysis does not include other health effects associated with elevated BP or with lead. Other effects of lead in adults can include nervous system disorders, anemia, and possible cancer effects.

From this analysis, EPA estimated that the final rule will yield no lead-related health benefits to adults.

Other regulatory options considered by EPA were found to yield lead-related benefits to adults. Table 14.7 summarizes lead-related benefits estimated for the 433 Upgrade Options. EPA estimated that the Directs + 413 to 433 Upgrade Option and the Directs + All to 433 Upgrade Option respectively would reduce hypertension among males by 53 and 60 cases annually. Both the 433 Upgrade Options would also reduce the annual incidence of premature mortality among men and women by approximately 0.1 cases. EPA estimated annual lead-related benefits for adults under the Directs + 413 to 433 Upgrade Option at $0.70 million (2001$) and under the Directs + All to 433 Upgrade Option at $0.79 million (2001$).

Table 14.7: National Adult Lead Annual Benefits (2001$) — 433 Upgrade Options[a,b]

Category		Directs + 413 to 433 Upgrade		Directs + All to 433 Upgrade	
		Reduced Cases	Mean Value of Benefits	Reduced Cases	Mean Value of Benefits
Men	Hypertension	53.47	$61,004	59.58	$67,982
	CHD	0.05	$4,155	0.06	$4,631
	CBA	0.02	$5,698	0.02	$6,350
	BI	0.01	$3,226	0.01	$3,596
	Mortality	0.07	$474,735	0.08	$529,125
Women	CHD	0.02	$1,662	0.02	$1,853
	CBA	0.01	$2,417	0.01	$2,694
	BI	0.01	$1,487	0.01	$1,658
	Mortality	0.02	$150,190	0.03	$167,417
Total Benefits			**$704,574**		**$785,304**

[a] Based on the Traditional Extrapolation.
[b] National Level Exposed Population:
(1) *Directs + 413 to 433 Upgrade*
Hypertension: 139,745 men ages 20 to 74;
CHD, CBA, BI, and mortality: 56,564 men and 62,666 women ages 45-74.
(2) *Directs + 413 + 50% LL Upgrade*
Hypertension: 139,745 men ages 20 to 74;
CHD, CBA, BI, and mortality: 56,564 men and 62,666 women ages 45-74.

Source: U.S. EPA analysis.

Table 14-8 summarizes lead-related benefits estimated for the Proposed/NODA Option. EPA estimated that this option would reduce hypertension among males by approximately 545 cases and the incidence of premature mortality among men and women by 0.96 cases annually. Lead-related benefits for adults under the Proposed/NODA Option would be $7.05 million annually, which substantially exceeds estimated benefits under the two 433 Upgrade Options.

Table 14.8: National Adult Lead Annual Benefits (2001$) — Proposed/NODA Option[a,b]

Category		Reduced Cases	Mean Value of Benefits
Men	Hypertension	545.25	$622,126
	CHD	0.54	$41,564
	CBA	0.17	$56,907
	BI	0.10	$32,197
	Mortality	0.73	$4,750,132
Women	CHD	0.22	$16,472
	CBA	0.10	$23,928
	BI	0.06	$14,714
	Mortality	0.23	$1,489,984
Total Benefits			**$7,048,025**

[a] Based on the Traditional Extrapolation.
[b] National Level Exposed Population:
Hypertension: 539,142 men ages 20 to 74;
CHD, CBA, BI, and mortality: 218,226 men and 241,768 women ages 45-74.

Source: U.S. EPA analysis.

14.5 Limitations and Uncertainties

This section discusses limitations and uncertainties in the lead-related benefits analysis. Developing dose-response functions depends on relating lead exposure to PbB levels, then evaluating PbB levels in relation to specific health outcomes. Quantitative dose-response functions for most health effects associated with lead exposure currently do not exist. For this reason, the analysis does not provide a comprehensive estimate of health benefits from reduced lead discharges from MP&M facilities.

Table 14.1 summarizes quantified and non-quantified health effects. Economic research does not always yield a complete evaluation, even for those effects that can be quantified. This uncertainly is likely to bias the estimate of lead-related benefits of the MP&M regulation downward. The analysis methodologies used here also involve significant simplifications and uncertainties. Section 13.3 discusses similar limitations and uncertainties associated with the assessment of risk associated with non-lead-related human health hazards and the possible direction of bias associated with sample design and benefits analysis by:

- occurrence location,
- estimated in-waterway concentrations of MP&M pollutants, and
- estimated exposed fishing population.

The next five sections discuss other omissions, biases, and uncertainties in the lead-benefit analysis. Table 14.9 provides a summary of this discussion.

14.5.1 Excluding Older Children

Recent research on brain development among 10- to 18-year-old children shows unanticipated and substantial growth in brain development, mainly in the early teenage years (Giedd et al., 1999). This growth appears to be a second “burst” of cell development in some brain areas, in addition to the previously recognized period of rapid growth during early childhood. One of lead’s fundamental effects is to disrupt the protective coating (myelin) on nerve cells. This disruption can lead to permanent impairment if it occurs during development. New research suggests that older children may be a hypersensitive sub-population, along with children aged 0 to 7. Excluding this sub-population from the analysis may significantly underestimate benefits from reduced lead discharges.

14.5.2 Compensatory Education Costs

This analysis assumes that compensatory education is required only for children with IQs less than 70, and that part-time special education costs are assumed to be incurred only from grades 1 through 12 (Section 14.2.4). This assumption underestimates compensatory education costs for the following reasons:

- Children with IQ scores between 70 and 85 will likely be assigned to special education or "slow" classes that will likely be smaller than regular classes and require more teacher attention. Children in this IQ range may frequently require more than 12 years to graduate and are more likely to drop out of school. Such children therefore require additional education costs.

- Compensatory education may begin before grade one. Some states (e.g., Connecticut) offer compensatory education programs for disadvantaged children beginning at age three.

This analysis is based on a study that measured the increased cost to educate children with low IQs attending a regular school, not a special education program (Kakalik et al., 1981). The cost to attend a special education program is generally much higher than that for regular schooling.

Some overlap may exist between estimates of the avoided costs of compensatory education due to reduced incidence of children with IQ below 70 and PbB levels above 20 µg/dL because children with PbB levels may also have low IQ scores. Estimating the magnitude of this overlap is, however, not feasible due to data paucity. In addition, the estimated avoided cost of compensatory education due to reduced incidence of children with PbB levels above 20 µg/dL is negligible compared to other benefits from reduced exposure to lead. Thus, this overlap does not introduce a significant bias in the estimate of total benefits from reduced exposure to lead to children.

14.5.3 Dose-Response Relationships

The dose-response functions described for each health outcome considered above generally quantify the adverse health effects expected from increased lead exposure. For children, these effects are defined in terms of changes in PbB. For adults, these effects are estimated in terms of changes in BP, which are in turn related to changes in PbB levels. Uncertainty is inherent in the dose-response functions, which are typically expressed in terms of the standard deviations of the dose-response coefficients used in the analysis. Any uncertainty affecting the dose-response coefficients will also indirectly affect the accuracy of this analysis.

14.5.4 Absorption Function for Ingested Lead in Fish Tissue

Numerous research groups have evaluated lead absorption under a variety of conditions. ATSDR reports a range of three percent to 45 percent in the studies they present, which consider lead intake with and without food (ATSDR, 1997). Absorption appears to be affected by total lead intake, with some studies showing a higher absorption proportion with higher doses. Animal studies show a saturation effect, which modifies absorption.

Lead's chemical form also determines its absorption rate. For example, lead sulfide has approximately 10 percent of the bioavailability of lead acetate (ATSDR, 1997). Particle size and solubility are also important absorption factors. EPA could not obtain data to describe lead's precise chemical form, particle size, and other physical parameters in fish tissue, which would allow more refined absorption estimates. These characteristics vary because MP&M facilities produce lead using different processes and release it in different forms.

An individual's nutritional status also affects lead absorption rates. People who are malnourished, particularly with respect to calcium and iron, have high absorption rates (ATSDR, 1997). EPA assumed that anglers were not malnourished, and made no adjustment for their nutritional status. See the section on lead absorption in Maddaloni (1998) for a discussion of factors influencing absorption. In the absence of data on lead incorporated into food, EPA considered data from studies of lead absorption during meals to be the most appropriate data to use in estimating absorption.

14.5.5 Economic Valuation

This analysis used IQ differentials to represent cognitive damage to children resulting from lead exposure. The economic analysis relates IQ level to annual earnings, which serve as the basis for valuing benefits from reduced lead exposure. IQ differentials are used rather than WTP, the preferred measure to use, because WTP values to avoid cognitive damage are not available. This analysis likely underestimates the value of an IQ point because special education and lost wages form only a portion of the costs associated with lost cognitive functioning. A simple IQ change analysis does not capture all the ways in which a child, family, and society are affected by the effects of lead-induced cognitive damage.

Dollar values associated with most of the adult health and welfare endpoints represent only some components of society's WTP to avoid these health effects. EPA used COI estimates to value reductions in CHD events, strokes, and hypertension. These values are likely to be downward-biased because the value of pain and suffering avoided is not included. Employed alone, these monetized effects will underestimate society's WTP.

Table 14.9: Key Omissions, Biases, and Uncertainties in the Lead-Benefit Analysis

Omissions/Biases/ Uncertainties	Directional Impact on Benefits Estimates	Comments
Excluding older children	downward	New research suggests that older children may be a hypersensitive sub-population, as children aged 0 to 7 are now considered. Excluding this sub-population from the analysis may significantly underestimate benefits from reduced lead discharges.
Compensatory education costs	uncertain	Assuming that compensatory education is required only for children with IQs less than 70 and that part-time special education costs are incurred from grades 1 through 12 underestimates the special education costs because: ▶ Children with IQ scores between 70 and 85 will likely be assigned to special education or "slow" classes, requiring more teacher attention, and taking longer to graduate or dropping out altogether. ▶ Compensatory education may begin before grade one. ▶ The cost to attend a special education program is generally much higher than that for regular schooling. A potential overlap exists between estimates of the avoided costs of compensatory education due to reduced incidence of children with IQ below 70 and PbB levels above 20 g/dL because children with PbB levels may also have low IQ scores. This overlap may introduce an upward bias in the estimate of the lead-related benefits to children. This bias is, however, negligible due to the magnitude of the avoided compensatory education cost estimates.
Dose-response relationship	uncertain	Uncertainty is inherent in the dose-response functions (expressed in changes in PbB for children, changes in BP for adults). Any uncertainty affecting the dose-response coefficients will also indirectly affect the accuracy of this analysis.
Absorption factor for lead in fish tissue	uncertain	Absorption rate appears to be affected by: ▶ total lead intake, with some studies showing a higher absorption proportion with higher doses; ▶ lead's chemical form. Because MP&M facilities produce lead using different processes and release it in different forms, EPA could not obtain data to describe lead's precise chemical form, particle size, and other physical parameters in fish tissue, which would allow more refined absorption estimates; ▶ an individual's nutritional status; and ▶ time of lead ingestion. In the absence of data on lead incorporated into food, EPA considered data from studies of lead absorption during meals to be the most appropriate data to use in estimating absorption.
Economic valuation	downward	The values associated with cognitive damage to children and adult health effects are likely to be downward-biased. For children, a simple IQ change analysis does not capture all effects of lead-induced IQ loss on a child, family, and society. The valuation of adults' health effects from lead exposure do not include the value of avoided pain and suffering. Employed alone, these monetized effects will underestimate society's WTP.
Overall impact	downward	

Source: U.S. EPA analysis.

GLOSSARY

absolute gastrointestinal absorption fraction: the fraction of lead in food ingested daily that is absorbed from the gastrointestinal tract.

acute toxicity: the ability of a substance to cause severe biological harm or death soon after a single exposure or dose. Also, any poisonous effect resulting from a single short-term exposure to a toxic substance. (http://www.epa.gov/OCEPAterms/aterms.html)

angina pectoris: a syndrome characterized by paroxysmal, constricting pain below the sternum, most easily precipitated by exertion or excitement and caused by ischemia of the heart muscle, usually due to a coronary artery disease, as arteriosclerosis. (www.infoplease.com)

arithmetic mean: the mean obtained by adding several quantities together and dividing the sum by the number of quantities. (www.infoplease.com)

atherothrombotic brain infarctions (BI): scientific name for a stroke.

bioavailability: degree of ability to be absorbed and ready to interact in organism metabolism. (http://www.epa.gov/OCEPAterms/bterms.html)

biokinetics: the study of movements of or within organisms. (www.infoplease.com)

biomarker: a physical, functional, or biochemical indicator of a certain process or event. It is commonly used to measure the progress of a disease, the effects of treatment, or the status of a condition.

blood lead (PbB): concentration level of lead in blood stream; usually expressed in µg/dL.

blood pressure: the pressure of the blood against the inner walls of the blood vessels, varying in different parts of the body during different phases of contraction of the heart and under different conditions of health, exertion, etc. (www.infoplease.com)

central tendency estimate: major trend in group of data.

cerebrovascular accident (CBA): stroke.

coronary heart disease (CHD): disorder that restricts blood supply to the heart; occurs when coronary arteries become narrowed or clogged due to the build up of cholesterol and fat on the inside walls and are unable supply enough blood to the heart.

diastolic: pertaining to or produced by diastole, or (of blood pressure) indicating the arterial pressure during the interval between heartbeats. (www.infoplease.com)

discounting: degree to which future dollars are discounted relative to current dollars. Economic analysis generally assumes that a given unit of benefit or cost matters more if it is experienced now than if it occurs in the future. The present is more important due to impatience, uncertainty, and the productivity of capital. This analysis uses a three percent discount rate to discount future benefits. (http://www.damagevaluation.com/glossary)

dose response: shifts in toxicological responses of an individual (such as alterations in severity) or populations (such as alterations in incidence) that are related to changes in the dose of any given substance.

dose-response assessment: 1. Estimating the potency of a chemical. 2. In exposure assessment, the process of determining the relationship between the dose of a stressor and a specific biological response. 3. Evaluating the quantitative relationship between dose and toxicological responses.

dose-response curve: graphical representation of the relationship between the dose of a stressor and the biological response thereto.

dose-response functions: see dose-response relationship.

dose-response relationship: the quantitative relationship between the amount of exposure to a substance and the extent of toxic injury or disease produced. (http://www.epa.gov/OCEPAterms/dterms.html)

encephalopathy: any brain disease. (www.infoplease.com)

GDP price deflator: measure of the percentage increase in the average price of products in GDP over a certain base year published by the Commerce Department. (http://www.damagevaluation.com/glossary.htm)

genotoxic: may cause chromosomal damage in humans leading to birth defects.

geometric mean (GM): for a set of n numbers $\{x_1, x_2, x_3, ..., x_n\}$ it is the n-th root of their product: $(x_1 * x_2 * x_3 ... x_n)^{1/n}$.

geometric standard deviation (GSD): a measure of the inter-individual variability in blood lead concentrations in a population whose members are exposed to the same environmental lead levels. For a lognormal distribution, GSD is the exponential of the standard deviation of the associated normal distribution.

half-life: time required for a living tissue, organ, or organism to eliminate one-half of a substance which has been introduced into it.

health endpoints: an observable or measurable biological event or chemical concentration (e.g., metabolite concentration in a target tissue) used as an index of an effect of a chemical exposure.

heme synthesis: creation of heme; an iron compound of protoporphyrin which constitutes the pigment portion or protein-free part of the hemoglobin molecule and is responsible for its oxygen-carrying properties.

Integrated Exposure, Uptake, and Biokinetics (IEUBK): the IEUBK model is an exposure-response model that uses children's environmental lead exposure to estimate risk of elevated blood lead (typically> 10 µg/dL) through estimation of lead body burdens in mass balance framework.

least-squares regression: a tool of regression analysis that computes a best-fit line to represent the relationship between two (or more) variables based on the principle that the squared deviations of the observed points from that line are minimized (see also: regression analysis).

lognormal distribution: a distribution of a random variable for which the logarithm of the variable has a normal distribution. (www.infoplease.com)

lognormally-distributed random variable: same as lognormal distribution.

marginal cost: the increase in total costs as one more unit is produced. (http://www.damagevaluation.com/glossary.htm)

multivariate: (of a combined distribution) having more than one variate or variable. (www.infoplease.com)

nephropathy: any kidney disease. (www.infoplease.com)

neurobehavioral deficits: neurologic effects as assessed by observation of behavior. These effects may include behavioral and attentional difficulties, delayed mental development, lack of motor and perceptual skills, and hyperactivity.

neurobehavioral function: see neurobehavioral deficits.

non-cancer health risks: include systemic effects, reproductive toxicity, and developmental toxicity.

normal distribution: a random variable X is normally distributed if its density is given by $f_x(x) = f(x; \mu, \sigma)$, where µ and σ are the mean and the variance of the distribution.

opportunity cost: the highest-valued sacrifice needed to get a good or service. (http://www.damagevaluation.com/glossary.htm)

p-value: the probability of obtaining a given outcome due to chance alone. For example, a study result with a significance level of $p \leq 0.05$ implies that 5 times out of 100 the result could have occurred by chance. (http://www.teleport.com/~celinec/glossary.htm)

pharmacokinetics: the study of the way drugs move through the body after they are swallowed or injected. (http://www.epa.gov/OCEPAterms/pterms.html)

probability distribution: a distribution of all possible values of a random variable together with an indication of their probabilities. (www.infoplease.com)

probit regression: a regression model, where the dependent variable is set up as a 0-1 dummy variable and regressed on the explanatory variables. The predicted value of the dependent variable could be interpreted as the probability that a certain event will take place (e.g., an individual will buy a car, visit a particular location, or get a specific disease).

quasi-steady state: almost not changing state.

regression analysis: a procedure for determining a relationship between a dependent variable, such as predicted success in college, and an independent variable, such as a score on a scholastic aptitude test, for a given population. The relationship is expressed as an equation for a line. (www.infoplease.com)

risk-based remediation goals (RBRG): target human health and environmental risk levels to be achieved via remedial actions at Superfund sites.

Technical Review Workgroup (TRW): a workgroup formed in 1994 to evaluate methodologies for adult lead risk assessment.

μg/L: microgram per liter

μg/dL: microgram per decaliter

willingness-to-pay (WTP): maximum amount of money one would give up to buy some good. (http://www.damagevaluation.com/glossary.htm)

ACRONYMS

ATSDR: Agency for Toxic Substances and Disease Registry
BI: atherothrombotic brain infarction
BP: blood pressure
CARB: California Air Resources Board
CBA: cerebrovascular accidents
CDC: Centers for Disease Control
CEPA: California Environmental Protection Agency
CHD: coronary heart disease
COI: cost of illness
GM: geometric mean
GSD: geometric standard deviation
IEUBK: Integrated Exposure, Uptake, and Biokinetics
NHANES: National Health and Nutrition Examination Surveys
NLSY: National Longitudinal Survey of Youth
PbB: blood lead
PPRG: Pooling Project Research Group
RBRG: risk-based remediation goals
TRW: Technical Review Workgroup
WTP: willingness-to-pay

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Chapter 15: Recreational Benefits

INTRODUCTION

The final ***Metal Product and Machinery (MP&M)*** regulation is expected to provide ecological benefits through improvements in the habitats or ecosystems (aquatic and terrestrial) that are affected by the MP&M industry discharges. Society is expected to value such ecological improvements by a number of mechanisms, including increased frequency and value of use of the improved habitat for recreational activities. In addition, individuals may also value the protection of habitats and species that are adversely affected by effluent dischargers even when they do not use or anticipate future use of the affected waterways for recreational or other purposes.

CHAPTER CONTENTS

This chapter presents EPA's analysis of ecological benefits from reduced effluent discharges to the nation's waterways as a result of the final MP&M regulation, the 433 Upgrade Options, and the Proposed/NODA option. EPA assessed ecological benefits in terms of reduced occurrence of pollutant concentrations in excess of AWQC protective of aquatic life and human health. For this analysis, EPA estimated the in-waterway pollutant concentrations of MP&M facility discharges for the baseline and the final rule and identified those reaches in which MP&M facility discharges would cause one or more pollutant concentrations to exceed ***ambient water quality criteria (AWQC)*** for aquatic species and human health.[1, 2] The change in the number of reaches with concentrations in excess of AWQC from the baseline to post-compliance scenarios provides a quantitative measure of the improvement in aquatic species habitat expected to result from the final regulation.

As discussed in Chapter 12, EPA performed all benefits analysis on a basis of the sample facility data. The Agency then extrapolated findings from the sample facility analyses to the national level using two alternative extrapolation methods: (1) traditional extrapolation and (2) post-stratification extrapolation. EPA also used the differential extrapolation technique in addition to both traditional and post-stratification approaches when a sample reach was estimated to receive discharges from multiple facilities. Appendix G provides detailed information on the extrapolation approaches used in this analysis.

Reducing concentrations of MP&M pollutants to below AWQC limits for protection of aquatic species and human health will generate benefits to users of water resources for recreation, including anglers, boaters, and viewers. These benefits include:

- increased value of the recreational trip or day, and
- increased number of days that consumers of water-based recreation choose to visit the cleaner waterways.

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[1] For this analysis, a reach is a length of river, shoreline, or coastline on which a pollutant discharge may be expected to have a relatively uniform effect on concentrations. The typical length of a reach in this analysis was five to ten kilometers, although some were considerably longer.

[2] AWQC set limits on pollutant concentrations that are assumed to be protective of aquatic life. Pollutant concentrations that exceed AWQC can harm organisms that live in or consume water. MP&M pollutants can also harm other organisms that consume these organisms. These organisms at risk include humans who may recreate in contaminated waters or consume aquatic organisms living in them.

EPA estimated national annual recreational use benefits for three water-based recreation activities (i.e., recreational fishing, boating, and viewing) and nonuse benefits, but did not estimate national swimming benefits due to data limitations.[3] EPA estimated the following recreational use benefits of the final MP&M rule (2001$):

- recreational fishing benefits range from $287,220 to $923,988 and from $187,123 to $601,976, based on the traditional and post-stratification extrapolation, respectively;

- near-water recreation (viewing) benefits range from $185,172 to $334,315 and from $120,639 to $217,805, based on the traditional and post-stratification extrapolation, respectively; and

- boating benefits range from $114,111 to $316,078 and from $74,343 to $205,924, based on the traditional and post-stratification extrapolation, respectively.

EPA also estimated nonuse benefits from improved water quality in the nation's surface water resulting from the final rule. Empirical estimates from surface water valuation studies indicate that nonuse values for water resources may be substantial because people who do not use or expect to use affected waterways for recreational or other purposes may still value protecting habitats and species impacted by effluent discharges (Harpman, et al., 1993; Fisher and Raucher, 1984; Brown, 1993). The Agency estimated that nonuse benefits will range from $293,252 to $787,190 and from $191,053 to $512,852, based on the traditional and post-stratification extrapolation, respectively.

EPA calculated the total value of enhanced water-based recreation opportunities by summing over the three recreation categories and nonuser value. Since recreational trips corresponding to fishing, boating, and wildlife viewing considered in this analysis are stochastically independent (i.e., only the primary activity is counted on each trip occasion), benefits from improved recreational opportunities corresponding to these activities are additive. The total annual recreational benefit based on the traditional extrapolation is estimated at $879,755 to $2,361,570 (2001$), with a midpoint estimate of $1,499,756 (2001$). Likewise, total annual recreational benefit based on the post-stratification extrapolation is estimated at $573,158 to $1,538,557 (2001$), with a midpoint estimate of $977,087 (2001$).

The analysis of recreational benefits presented in this chapter uses the ***National Demand Study (NDS)*** data to estimate the number of participants in wildlife viewing and boating in the counties affected by MP&M discharges.[4] To estimate the number of recreational fishermen, EPA used fishing license data. The NDS survey asked respondents to report the number of recreational trips taken annually for the *primary purpose* of boating and wildlife viewing. The Agency used these data to estimate the number of participants and the number of recreational trips taken annually by state and activity type. Appendix N summarizes this information.

EPA chose to use fish license data rather than the NDS data to estimate the number of recreational anglers fishing the MP&M reaches because these data are often available at the county level and therefore provide location-specific information. Although the use of the NDS and fish license data yields similar estimates of the number of recreational anglers at the state level (see Chapter 21) fish license data are likely to be more accurate at the county level. The use of the fish license data in the recreational fishing benefit analysis also provides consistency with other parts of the benefits analysis (see Chapters 13 and 14 for detail).

Benefit categories examined in this chapter are different from and generally do not overlap with benefits associated with reduced risk to human health discussed in Chapter 13. Nevertheless, there is some likelihood that the valuation of ecological benefits based on enhanced recreational fishing overlaps to a degree with the valuation of human health benefits from reduced cancer risk via fish consumption.

[3] Fewer water bodies are designated for primary contact recreation, such as swimming, than for secondary contact recreation, such as boating and fishing. Assessing recreational swimming benefits requires first obtaining information on designated uses of the sample MP&M reaches from the 305(b) database. This analysis was not feasible due to resource and time constraints.

[4] Additional information on the NDS survey can be found in Chapter 21.

15.1 ECOLOGICAL IMPROVEMENTS FROM THE MP&M REGULATION

15.1.1 Overview of Ecological Improvements

Many MP&M pollutants can adversely affect the survival, growth, and reproduction of aquatic organisms. Such effects are ecologically significant when they affect the size, structure, or function of populations:

- MP&M pollutants can affect ***population size*** by reducing prey, and by affecting development or reproduction in sensitive life stages of target species;
- MP&M pollutants can alter ***population structure*** by impairing sensitive age groups or affecting the development or maturation rates of target species; and
- MP&M pollutants can impact ***population function*** by decreasing genetic diversity and changing interactions among different populations in the affected areas.

MP&M pollutants may also contaminate fish tissue and therefore decrease the value of fishery resources. Thus, the final MP&M regulation may generate a broad range of ecological effects by reducing MP&M pollutant discharges. Ecological effects associated with reductions in MP&M discharges may include:

- recovery of populations of aquatic species that are particularly sensitive to MP&M pollutants;
- decreases in noxious algae, which affect the taste and odor of the receiving waters;
- increases in the concentrations of ***dissolved oxygen*** (DO) in the water column;
- improvements in the natural assimilative capacity of the affected waterways;
- decreases in fish tissue contamination; and
- terrestrial life benefits.

Improvements in aquatic species habitat are expected to improve the quality and value of water-based recreation and nonuse values of the affected resources. Recent studies valuing recreational fishing showed that the value of water resources for recreational fishing increases as the level of toxic contamination in fish tissue decreases (Lyke, 1993; Phaneuf et al., 1998; and Jakus et al., 1997). Thus, knowing that the water is cleaner and does not contain any or contains fewer pollutants that harm humans and aquatic life, increases individuals' enjoyment of their recreational experience. The value of a recreational fishery also increases from increased number, size, diversity, and health of recreational fish species.

Participants in other water-based recreation, such as boating and wildlife viewing, will also benefit from improved abundance and diversity of aquatic and terrestrial species. For example, wildlife viewers may benefit from improved abundance of piscivorous birds (e.g., osprey and cormorants) whose population is likely to increase due to an increase in the forage fish populations. Boaters may benefit from enhanced opportunities for companion activities, such as fishing and wildlife viewing (e.g., piscivorous birds) and from improved water clarity and smell. Reducing conventional pollutant loadings will also improve visual aesthetics, thereby enhancing all water-based recreation experiences.

15.1.2 Quantification of Ecological Improvements

EPA evaluated potential impacts to aquatic life from the final MP&M regulation by estimating in-waterway concentrations of pollutants discharged by MP&M facilities and comparing those concentrations within AWQC limits for protection of aquatic species. Pollutant concentrations in excess of AWQC limits indicate a significant detriment to the aquatic species habitat. EPA expects that eliminating these exceedances as the result of the MP&M regulation will significantly improve aquatic species habitat and thus provide a quantitative measure of ecological benefit for this regulatory analysis.

For this analysis, EPA estimated in-waterway concentrations for all MP&M pollutants for which AWQC limits are available. Of the 132 MP&M pollutants of concern, AWQC values are available for 114 pollutants.[5] Table I.3 in Appendix I lists the pollutants evaluated in this analysis and their acute and chronic aquatic life AWQC. The acute value is the maximum allowable one-hour average concentration at any time at which aquatic life can survive. The chronic value is the average concentration of a toxic pollutant over a four-day period at which aquatic life is not unacceptably affected. The endpoints of concern are one or more sub-lethal responses, such as changes in reproduction or growth in the affected organisms. The chronic levels should not be exceeded more than once every three years.

EPA used the mixing and dilution methods outlined in Appendix I to estimate the in-waterway concentrations resulting from MP&M facility discharges. Acute and chronic exposure concentrations for each pollutant are calculated on the basis of ***7Q10*** and ***1Q10*** stream flow rates, where 7Q10 is the lowest consecutive seven-day average flow with a recurrence interval of ten years, and 1Q10 is the lowest one-day average flow with a recurrence interval of ten years. For reaches to which more than one sample MP&M facility discharge, EPA summed the discharge values by pollutant for all known sample facilities discharging to the reach.

EPA first identified the MP&M discharge reaches in which MP&M discharges alone caused one or more pollutant concentrations to exceed AWQC limits for aquatic species under the baseline discharge level. If concentrations of all MP&M pollutants exceeding the limits in the baseline fell below AWQC limits as a result of the final rule, then aquatic species habitat conditions on that discharge reach would likely improve significantly as a result of the final regulation. The final regulation would result in partial aquatic habitat improvements if concentrations of some, but not all, MP&M pollutants fell below their AWQC limits. Although not explicitly accounted for in this analysis, species habitat conditions are likely to improve whenever in-waterway concentrations are reduced, regardless of whether or not they fall to levels below aquatic AWQC.

EPA's analysis based on the traditional extrapolation method indicates that pollutant concentrations at current industry discharge levels exceed acute exposure criteria for protection of aquatic species on 18 receiving reaches, and exceed chronic exposure criteria for protection of aquatic species on 353 receiving reaches.[6] EPA estimates that the final rule would eliminate concentrations in excess of the acute aquatic life exposure criteria on nine reaches, and would eliminate concentrations in excess of the chronic aquatic life exposure criteria on nine reaches.

Similarly, EPA's analysis based on the post-stratification extrapolation method indicates that baseline pollutant concentrations at current industry discharge levels exceed acute exposure criteria for protection of aquatic species on 15 reaches, and exceed chronic exposure criteria for protection of aquatic species on 350 reaches. EPA estimates that the final rule would eliminate concentrations in excess of the acute aquatic life exposure criteria on six reaches, and would eliminate concentrations in excess of the chronic aquatic life exposure criteria on six reaches. Table 15.1 summarizes these results.

15.1.3 Benefiting Reaches

As a first step in estimating the monetary value of improvements in the aquatic habitats affected by MP&M discharges from the final MP&M rule, EPA identified reaches that are likely to experience significant water quality improvements from reduced MP&M discharges due to the final MP&M rule (hereafter, ***benefiting reaches***). A reach is considered to benefit from the MP&M rule if at least one AWQC exceedance is eliminated due to reduced MP&M discharges. This approach differs from some past approaches where EPA took credit for pollution reductions only in cases where all AWQC exceedances are eliminated. EPA believes that the latter approach significantly underestimates benefits from reduced pollutant discharges.

This analysis combines two AWQC calculation procedures:

- analysis of in-waterway concentrations relative to human health AWQC limits described in Chapter 13,[7] and

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[5] Facilities in the Oily Wastes subcategory discharge 122 of the 132 POCs evaluated. See Chapter 12 for detail.

[6] This analysis used baseline pollutant loads for direct and indirect dischargers belonging to all subcategories considered for regulation.

[7] Although EPA estimated the value of reduced cancer risk from consumption of contaminated fish tissue, the Agency was unable to estimate the value of reduced systemic risk from consumption of fish caught in the reaches affected by MP&M discharges (see Chapter 13). The recreational benefits analysis presented in the following sections assumes that some of the value of reduced systemic health risk is implicitly captured in the increased value of water resources from reduced occurrence of human health-based AWQC exceedances. For

- analysis of in-waterway concentrations relative to aquatic life AWQC limits described in the preceding section of this chapter.

Table 15.1 summarizes the number of reaches with estimated baseline concentrations that exceed AWQC limits for either human health or aquatic species, and the number of those reaches where the regulation is estimated to eliminate or reduce exceedances. Based on the traditional extrapolation, the combined analysis over *all* AWQC limit categories (i.e., acute and chronic aquatic life and human health) indicates that MP&M pollutant concentrations would exceed at least one AWQC limit on 395 reaches as the result of baseline MP&M discharges. The expected discharge reductions from the final rule eliminate exceedances on nine of these discharge reaches, leaving 386 reaches with concentrations of one or more pollutants that exceed AWQC limits.

Likewise, based on the post-stratification extrapolation, the combined analysis indicates that MP&M pollutant concentrations would exceed at least one AWQC limit on 426 reaches as the result of baseline MP&M discharges. The expected discharge reductions from the final rule eliminate exceedances on six of these discharge reaches, leaving 420 reaches with concentrations of one or more pollutants that exceed AWQC limits.

EPA assigned full benefits in situations where the rule eliminates all AWQC exceedances and partial benefits where the rule eliminates one or more, but not all, AWQC exceedances. EPA calculates partial benefits as the ratio of the AWQC exceedances removed by reducing MP&M discharges to the total number of AWQC exceedances caused by MP&M facilities in the baseline. For example, if the MP&M rule removes seven out of a total ten baseline AWQC exceedances on a benefiting reach, the Agency attributes a 70 percent benefit to the MP&M regulation, where 100 percent would represent an "AWQC exceedance-free" level.

Table 15.1: Estimated MP&M Discharge Reaches with MP&M Pollutant Concentrations in Excess of AWQC Limits for Protection of Aquatic Species or Human Health

Regulatory Status	Number of Reaches with Concentrations Exceeding AWQC Limits				Total Number of Reaches with Concentrations Exceeding AWQC Limits	Number of Benefiting Reaches	
	AWQC Limits for Aquatic Species		AWQC Limits for Human Health			All AWQC Exceedances Eliminated	Reaches with Some Exceedances Eliminated
	Acute	Chronic	H20 and Organisms	Organisms Only			
Selected Option: Traditional Extrapolation							
Baseline	18	353	78	21	395	N/A	N/A
Final Option	9	344	78	21	386	9	0
Selected Option: Post-Stratification Extrapolation							
Baseline	15	350	112	21	426	N/A	N/A
Final Option	9	344	112	21	420	6	0

Note: In the baseline, the total number of reaches with concentrations exceeding AWQC limits does not equal the sum of the numbers in the separate analysis categories because some reaches were estimated to have concentrations in excess of AWQC limits for more than one analysis category.

Source: U.S. EPA analysis

Surface water valuation studies show that benefits from partial improvements are likely to be considerable. For example, Carson and Mitchell (1993) found that almost nine out of ten individuals indicated that "halfway" improvements are worth the same as a complete improvement in water quality. The remaining one out of ten individuals were willing to pay a reduced amount for partial improvements in water quality.

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example, some studies showed that anglers place a much higher value on fishery resources that are safe for consumption (Lyke, 1993 and Phaneuf, 1997).

The effects of partially removing AWQC exceedances, however, are difficult to generalize. The overall improvement in surface water quality from reduced toxic loadings will depend on the amount and duration of exceedances, together with the kinds of chemical(s) that are removed from the mixture by regulatory action. AWQC are developed on a chemical-by-chemical basis; they are not designed to assess the toxicity of multiple chemicals. In most cases, the toxicities of chemicals in a mixture are considered additive (i.e., the total toxicity is the sum of the toxicities of the individual chemicals). Total toxicity decreases by the amount of a chemical removed from the mixture. Benefits to sensitive aquatic species (i.e., amphibians, fish, benthic invertebrates, zooplankton) could occur if the concentration of one chemical fell below its AWQC even when two or more other chemicals still were at or exceeding their respective AWQC. The reason is that the total toxic pressure in the receiving water decreases so that a smaller fraction of the most sensitive species remain affected. For example, consider a case in which three chemicals exceeding their chronic AWQC adversely affect 7 percent of all aquatic species in a receiving water. If certain species are particularly sensitive to one of the three chemicals, then eliminating the AWQC exceedance for this chemical would lower the percentage of sensitive species being adversely affected.

15.1.4 Geographic Characteristics of MP&M Reaches

EPA cannot identify all of the specific reaches affected by MP&M facilities that reduce discharges under the final rule because location is known only for the facilities included in the random stratified sample. EPA assumes that facilities represented by the sample facility have the same environmental and geographic characteristics that affect benefits from the final rule. These characteristics include water body type and physical characteristics (e.g., stream flow conditions), populations residing near the water body, and the number of potential recreational users affected.

The analysis of the sample reach locations indicates that sample MP&M reaches tend to be located in heavily populated areas. For example, approximately 35 percent of sample reaches receiving discharges from sample MP&M direct dischargers are located adjacent to counties with populations of at least 500 thousand residents. These reaches have a greater number of potential recreational users than do reaches in less populated areas.

15.2 Valuing Economic Recreational Benefits

The final MP&M rule will improve aquatic habitats by reducing concentrations of ***priority (i.e., toxic)***, ***nonconventional***, and ***conventional*** pollutants in water. In turn, these improvements will enhance the quality and value of water-based recreation, such as fishing, wildlife viewing, camping, waterfowl hunting, and boating. The Agency used the estimated increase in the monetary value of recreational opportunities for fishing, boating, and wildlife viewing as a partial measure of the economic benefit to society from the improvements to aquatic species habitat expected to result from the final MP&M regulation. The Agency also estimated nonuse benefits from improvements in aquatic habitats and ecosystems that are affected by the MP&M industry discharges.

This analysis uses a ***benefits transfer*** approach to monetize changes in water resource recreational values for reaches affected by MP&M discharges.[8] This approach builds upon an analysis of applicable surface water valuation literature to estimate the total ***WTP*** value (including both use and nonuse values) for improvements in surface water quality.

15.2.1 Transferring Values from Surface Water Valuation Studies

EPA identified several surface water evaluation studies that quantified the effects of water quality improvements on various water-based recreational activities. The Agency used the following technical criteria for evaluating study transferability (Boyle and Bergstrom, 1990):

- The environmental change valued at the study site must be the same as the environmental quality change caused by the rule (e.g., changes in toxic contamination vs changes in turbidity);
- The populations affected at the study site and at the policy site must be the same (e.g., recreational users vs nonusers);

[8] Benefits transfer involves the application of value estimates, functions, and/or models developed in one context to address a similar resource valuation question in another context.

- The assignment of property rights at both sites must lead to the same theoretically appropriate welfare measure (e.g., willingness-to-pay vs willingness to accept compensation).

In addition to the above criteria, the Agency considered authors' recommendations regarding robustness and theoretical soundness of various estimates.

Existing studies are unlikely to meet all of the above criteria. Boyle and Bergstrom (1990) reported that most researchers will likely encounter problems with at least one criterion. This analysis is no exception. The major limitation in performing the national analysis is the comparability of the water quality changes considered in the original studies with the water quality changes considered in this analysis. These comparisons are discussed below.

The Agency used eight of the most comparable studies and calculated the changes in recreation values resulting from water quality improvements (as a percentage of the baseline value) implied by those studies. EPA took a simple mean of upper- and lower-bound estimates from these studies to derive a range of percentage changes in the water resource values due to water quality improvements. The studies used for benefits transfer in the MP&M regulatory analysis included Lyke (1993), Jakus et al. (1997), Montgomery and Needelman (1997), Phaneuf et al. (1998), Desvousges et al. (1987), Lant and Roberts (1990), Farber and Griner (2000), and Tudor et al. (2002). Appendix K presents WTP values for various water quality improvements and summarizes EPA's reasoning for selecting specific WTP estimates for benefits transfer. Each of the eight studies and the WTP values selected for benefits transfer are discussed briefly below.

Lyke's (1993) study of the Wisconsin Great Lakes open water sport fishery showed that anglers may place a significantly higher value on a contaminant-free fishery than on one with some level of contamination. Lyke estimated the value of the fishery to Great Lakes trout and salmon anglers if it were improved enough to be "completely free of contaminants that may threaten human health," and found that this value would add between 11 and 31 percent of the fishery's current value.

Jakus et al. (1997) used a repeated discrete choice ***travel cost (TC)*** model to examine the impacts of sport-fishing consumption advisories in eastern Tennessee. The model controlled for anglers' knowledge of advisories, the type of angler (i.e., fish consumption vs. catch and release), and catch rate. The estimated welfare gain (as a percentage of baseline) from cleaning up six reservoirs and removing these advisories ranges from six to 8 percent. These estimates are below Lyke's estimated 11 to 31 percent range, due to the difference in methodology used. The TC method captures use values only, while the combined TC and stated preferences method used in Lyke captures both the use and nonuse components of the resource value to users. Differences in the fisheries and user populations may also affect the estimated percentage changes in the resource value.

Montgomery and Needelman (1997) estimated benefits from removing "toxic" contamination from lakes and ponds in New York State. They used a binary variable as their primary water quality measure, which indicates whether the New York Department of Environmental Conservation considers water quality in a given lake to be impaired by toxic pollutants. The model controls for major causes of impairments other than "toxic" pollutants to separate the effects of various pollution problems that affect the fishing experience. The estimates from Montgomery and Needelman imply that removing "toxic" impairments in all New York lakes and ponds would increase recreational fishing value by 13.7 percent.

Phaneuf et al. (1998) studied angling in the Wisconsin Great Lakes. They estimated changes in recreational fishing values resulting from a 20 percent reduction of toxin levels in lake trout flesh. The study uses a TC model to value water quality improvements when corner solutions are present in the data. Corner solutions arise when consumers visit only a subset of the available recreation sites, setting their demand to zero for the remaining sites. Phaneuf et al. found that improved industrial and municipal waste management results in general water quality improvement. This improvement leads in turn to a 20 percent decrease in fish tissue toxin levels, yielding a welfare gain of $166.21 (2001$) per angler per year.[9] This estimate implies that recreational fishing values would increase by approximately 27.5 to 34.3 percent from reduced toxin levels. This analysis estimates use values only.

Desvousges et al. (1987) used findings from a ***contingent valuation (CV)*** survey to estimate WTP for improved recreational fishing from enhanced water quality in the Pennsylvania portion of the Monongahela River. In a hypothetical market, each survey respondent was asked to provide an option price for different water quality changes, including "raising

[9] The study used the 1989 survey data on recreational angling in Wisconsin's Great Lakes. Therefore, this analysis assumes that all estimates in the original study are in 1989 dollars.

the water quality from suitable for boating (hereafter, "boatable" water) to a level where gamefish would survive (hereafter, "fishable" water)."

In applying Desvousges et al. for the MP&M analysis, EPA assumed that reaches with AWQC exceedences under the baseline conditions are likely to support rough fishing but may not be clean enough to support gamefishing. Removing AWQC exceedences is therefore comparable to shifting water quality from "boatable"to "fishable." This is a relatively conservative assumption. Desvousges et al. found that improving water quality from "boatable" to "fishable" would yield a 5.9 to 7.9 percent increase in water resource value to recreational anglers.

Lant and Roberts (1990) used a CV study to estimate the recreational and nonuse benefits of improved water quality in selected Iowa and Illinois river basins. River quality was defined by means of an interval scale of "poor," "fair," "good," and "excellent." The authors defined "fair" water quality as adequate for boating and rough fishing and "good" water quality as adequate for gamefishing.

For the MP&M analysis, EPA assumes that eliminating AWQC exceedences is roughly equivalent to shifting water quality from "fair" to "good." The estimates from this study imply an increase of 9.7 to 13.1 percent in recreational fishing value from improving water quality from "fair" to "good."

Farber and Griner (2000) used a CV study to estimate changes in water resource values to users from various improvements in water quality in Pennsylvania. The study defines water quality as "polluted," "moderately polluted," and "unpolluted" based on a water quality scale developed by EPA Region III: "Polluted" streams are unable to support aquatic life; "moderately polluted" streams are somewhat unable to support aquatic life; and "unpolluted" streams adequately support aquatic life. Streams unable to support aquatic life (i.e., "polluted") are likely to be affected by environmental stressors unrelated to MP&M discharges, such as acidity or severe oxygen depletion.

The MP&M analysis assumes that most streams affected by MP&M facility discharges are moderately polluted; i.e., these streams support aquatic life, but sensitive species may be adversely affected by MP&M pollutants that exceed AWQC values protective of aquatic life. Removing all AWQC exceedences would make such streams unpolluted. The estimates from this study imply that improving water quality from "moderately polluted" to "unpolluted' would yield an increase in recreation fishery value ranging from 3.9 to 9 percent.

Tudor et al. (2002) used a TC model to estimate changes in water resource recreation values resulting from eliminating MP&M pollutant concentrations in excess of AWQC limits at recreation sites in Ohio.[10] The study involves four recreation activities -- fishing, boating, near-water recreation, and swimming -- and covers most recreationally-important water bodies in all Ohio counties. The study considers two types of water quality effects from MP&M pollutants on consumers' decisions to visit a particular water body:

(1) visible or otherwise perceivable effects (e.g., turbidity and odor); and
(2) "toxic" effects that are not directly perceivable by consumers.

Because priority and nonconventional pollutants at high enough concentrations may adversely affect aquatic species, "toxic" effects may be indirectly observable via species abundance and diversity. The study uses a dummy variable to account for effects of "toxic" MP&M pollutants, identifying recreation sites at which estimated concentrations of one or more MP&M pollutants exceed AWQC for protection of aquatic life. The study estimated that eliminating AWQC exceedances and reducing TKN concentrations would yield per trip benefits of $1.34, $1.78, $.60, and $0.33 (2001$) from improved fishing, boating, wildlife viewing, and swimming opportunities, respectively. The estimated changes in the recreational use value of Ohio water resources, are 0.77, 1.67, and 0.77 percent for fishing, boating, and wildlife viewing, respectively. This analysis estimates use values only.

With the exception of the Tudor et al. (2002) study, the types of water quality changes assessed in these studies are only roughly comparable to those studied in the MP&M analysis. Whereas the analysis of the final MP&M regulation and Tudor et al. (2002) assessed the impact of eliminating AWQC exceedances, the other studies used other measures of water quality improvement. EPA addressed the differences in measurement between the other studies and the MP&M analysis by linking

[10] Preliminary results of this study were presented at the annual American Agricultural Economic Association meeting (Tudor et al., 1999a) and at the annual Northeastern Agricultural and Resource Economic Association Meeting (Tudor et al., 1999b). EPA subjected this study to a formal peer review by experts in the natural resource valuation field. The peer review concluded that EPA had done a competent job, especially given the available data. This study can be found in Chapter 21. The peer review report is in the docket for the rule.

water quality changes expected from the MP&M regulation to the type of water quality changes assessed in the other studies. EPA assumed that eliminating AWQC exceedances is roughly comparable to the following discrete water quality changes:[11]

- "achieving a contaminant free fishery;"
- reducing the level of toxins in fish tissue;
- removing fish consumption advisories (FCA); and
- improving water quality from "boatable" to "fishable," from "fair" to "good," and from "moderately polluted" to "unpolluted."

The MP&M analysis uses the estimates derived from the eight surface water evaluation studies described above to calculate a range of national WTP values. The following sections present the methodology and relevant values used to estimate the value of improved fishing, wildlife viewing, and boating opportunities resulting from the MP&M regulation.

15.2.2 Recreational Fishing

The MP&M rule will improve the recreational angling experience by reducing concentrations of priority, nonconventional, and conventional contaminants in water. EPA estimated the benefits of these reductions by estimating:

- the number of recreational fishing days on benefiting reaches;
- the baseline fishery value of each benefiting reach; and
- changes in recreational fishery value, using values from the available surface water valuation studies.

a. Number of recreational fishing days

EPA calculated the annual number of person-days of recreational fishing for each benefiting reach using a two-step approach:

❖ ***Participating population***

The geographic area from which anglers would travel to fish a reach is assumed to include only those counties that abut a given reach. As noted in Chapter 13, this assumption is based on the finding in the 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation that 65 percent of anglers travel less than 50 miles to fish (U.S. Department of the Interior, 1993). NDS data showed that recreational anglers travel from 20 to 66 miles to their destination, with an average one-way travel distance of 30 miles.[12,13]

EPA estimated the population participating in recreational fishing using the number of licensed fishermen in counties bordering MP&M discharge reaches using the following steps:

- assume that fishing activity among these anglers is distributed evenly among all reach miles within those counties;
- compute the length of the MP&M reach as a percentage of total reach miles within corresponding counties;
- multiply the estimated ratio by the total fishing population in counties abutting the reach to estimate the number of anglers who may fish an MP&M reach; and

[11] Section 15.1.3 discusses a method used for estimating partial water quality improvements.

[12] See Chapter 21 for detail on the NDS data.

[13] These estimates exclude outliers.

- reduce the number of anglers by 20 percent in reaches where MP&M and other pollutants have required a fish consumption advisory. This reduction is an estimate of angler response to the presence of a fish consumption advisory.[14]

❖ ***Average number of fishing days***

Anglers generally participate in recreational fishing several times a year. The **U.S. Fish and Wildlife Service (FWS)** provides estimates of the average number of fishing days per angler in each state. The FWS estimates range from 10.5 days per angler in Arizona to 21.1 days per angler in Alabama for freshwater fishing, and 7.3 days per angler in Louisiana to 18.7 days per angler in Virginia for saltwater fishing.[15]

EPA calculated the total number of angler days by multiplying the number of recreational anglers for each benefiting reach by the average number of fishing days for the reach (based on the state in which the reach is located).

b. Baseline fishery value

The net value of a recreational fishing day is the total value of the fishing day exclusive of any fishing-related costs (e.g., license fees, travel costs, bait, tackle, charter boats, etc.) incurred by the angler.

EPA used two recreational fishing valuation studies (Bergstrom and Cordell (1991) and Walsh et al. (1992)) to calculate the net economic value per recreational fishing day under the baseline conditions. Both studies used a meta-analysis of recreational fishery valuation studies to estimate per-day values of the three types of recreational fishing: warmwater, coldwater, and anadromous. Based on the two studies, EPA developed an average per-day value for each type of recreational fishing. This analysis uses low and high average benefit values for fishing days of $28.11 and $60.43 (2001$) to estimate a range of the baseline fishery values.

Table 15.2: Baseline Values of Fishing

Fishery Type	Per-day Value (2001$)[a]		Average Per-day Value (2001$)
	Bergstrom and Cordell (1991)[b]	Walsh et al. (1992)[c]	
Warmwater	$19.52	$36.70	$28.11
Coldwater	$27.77	$47.71	$37.74
Anadromous	$36.73	$84.15	$60.43
Range of above			$28.11 - $60.43

[a] Original study values were adjusted to 2001 dollars based on the relative change in CPI from 1987 to 2001.
[b] Study location: various U.S. locations. Estimating approach: meta-analysis of TC studies.
[c] Study location: various U.S. locations. Estimating approach: meta-analysis of CV and TC studies.

Source: U.S. EPA analysis

EPA calculated the total baseline value for each fishery located on a benefiting reach by multiplying the estimated net value of a recreational fishing day by the total number of fishing days calculated in subsection (a) above. Applying facility weights and summing over all benefiting reaches provides a total baseline recreational fishing value for MP&M reaches expected to benefit from the elimination of pollutant concentrations in excess of AWQC limits.

[14] See Belton et al. (1986), Knuth and Velicer (1990), Silverman (1990), West (1989), Connelly et al. (1992), and Connelly and Knuth (1993) for more information on angler response to fish advisories.

[15] These averages reflect participation levels in the 48 contiguous states. No sample facility is located in Hawaii or Alaska.

c. Changes in recreational fishery value

Expected benefits from the final MP&M regulation include an increase in the quality of an angler's recreational opportunities and/or the number of days an angler chooses to fish each season.

EPA assumes that the expected welfare gain for recreational anglers is a function of changes in the overall quality of all recreational opportunities available to each angler. Recreational anglers residing in the counties abutting MP&M reaches will therefore benefit from improved recreational opportunities whether or not they actually visit an MP&M reach.

EPA used the eight studies discussed above to calculate the changes in recreation values from water quality improvements (as a percentage of baseline) implied by those studies. Table 15.3 compiles information on the baseline values, values of changes in water quality, and percentage changes in values reported or implied by these studies.

Table 15.3: Studies Estimating Changes in Value of a Recreational Fishery

Study	Type of Water Quality Change Valued	Baseline Value of Recreational Angling (2001$)	Value of Water Quality Change (2001$)	Value of Change as % of Baseline	Type of Benefits Included
Lyke (1993)	Fish tissue is completely free of toxic contaminants that may threaten human health	$95.0-$119.0 million per year [a]	$10.5-$37.1 million per year [a]	11% - 31%[a]	Use and nonuse values for recreational anglers
Jakus et al. (1997)	Lifting FCAs	$26.0-$52.6 per trip	$2.0-$3.2 per trip	6.0% - 8.0%	Use values for recreational anglers
Montgomery and Needelman (1997)	Elimination of toxic impairment	$656.6 per angler per year [b]	$90.3 per angler per year	13.7%	Use values for recreational anglers
Phaneuf at al. (1998)	20% reduction of toxic contamination in trout flesh	$484.5 - $605.8 per angler per year [a]	$166.2 per angler per year	27.5% - 34.3%	Use values for recreational anglers
Desvousges et al. (1987)	Improvement from "boatable" to "fishable"	$28.11- $37.73 per trip [c]	$2.21 per trip [d]	5.9% - 7.9%	Recreational and nonuse values to users
Lant and Roberts (1990)	Improvement from "fair" to "good"	$28.11- $37.73 per trip [c]	$3.67 per trip [e]	9.7% - 13.1%	Recreational and nonuse values to users
Farber and Griner (2000)	Improvement from "moderately polluted" to "unpolluted"	$28.11- $37.73 per trip [c]	$1.49-$2.55 per trip [f]	3.9% - 9.0%	Recreational use values to users and nonusers
Tudor et al. (2002)[g]	Elimination of AWQC exceedances	$173.34 per trip	$1.34 per trip	0.77%	Use values for recreational anglers
Average percentage change in recreational fishery value (based on above studies)[h]				9.8% -14.7 %	Recreational and nonuse values to users

[a] The baseline fishery value for the study site location is based on the baseline fishery value reported in Lyke (1993). The study used data from two mail surveys conducted in 1989 at the University of Wisconsin-Madison. These surveys were originally used by Lyke (1993).
[b] Based on the average value for a coldwater fishing day of $37.74 (see Table 15.2), multiplied by the average number of freshwater (non-Great Lakes) angling days per year in New York State (17.4 days, USFWS, 1996).
[c] Range based on the range of values for a fishing day used in this analysis (see Table 15.2);
[d] Based on the value of water quality improvement of $36.79 per year (updated from 1987 dollars reported in Desvousges et al., 1987). divided by the average number of freshwater angling days per year in Pennsylvania (16.6 days, USFWS, 1996).
[e] Based on the value of water quality improvement of $57.81 per year (updated from 1990 dollars reported in Lant and Roberts) divided by the average number of freshwater angling days per year in Iowa and Illinois (16.6 and 15.5 days, USFWS, 1996).
[f] Based on the values of water quality improvements ranging from $24.55 to $41.93 per year reported in Farber and Griner (2000), divided by the average number of freshwater angling days per year in Pennsylvania (16.6 days, USFWS, 1996).
[g] See Chapter 21 of this report for detail. The baseline value of recreational fishery is based on the estimated mean value of water resources for recreational anglers reported by Tudor et al. (2002). The estimated median value of recreational fishing is $175.48. These values were derived from a September 23, 2002 analysis.
[h] EPA took a simple mean of lower- and upper-bound estimates from the eight studies to calculate a range of percentage changes in the recreational fishery value from improved water quality conditions. When only one value is available from the study (i.e., Tudor et al., 2002), EPA used this value in calculating both the lower- and upper-bound estimates.

Source: U.S. EPA analysis

EPA used the percentage change in the fishery value implied by the eight studies to estimate increased recreational fishing values for all MP&M reaches in which the regulation eliminates AWQC exceedances of one or more MP&M pollutants. That is, the Agency estimated benefits for all MP&M discharge reaches where at least one AWQC exceedance is eliminated due to reduced MP&M discharges. As noted above, EPA took a simple mean of lower- and upper-bound estimates from the eight studies described above to calculate a range of percentage changes in the recreational fishery value from reduced MP&M discharges. These studies yielded estimates of increased value ranging from 9.8 to 14.7 percent. Multiplying these percentages by the baseline value of fisheries located on benefiting reaches yielded a range of benefits from eliminating pollutant concentrations in excess of AWQC limits.

Table 15.4 below summarizes the results of EPA's recreational fishing benefits analysis.

Table 15.4: Summary of Recreational Fishing Benefits (2001$)

	Number of Benefiting Reaches	Participating Population (millions)	Average Number of Fishing Days	Total Angler Days (millions)	Baseline Fishery Value/ Rec. Day	Baseline Fishery Value ($ millions)	% Change in Fishery Value	MP&M Benefits
Selected Option: Traditional Extrapolation								
Low Estimate	9	0.98	17.3	16.98	$28.11	$477	9.8%	$287,220
High Estimate	9	0.98	17.3	16.98	$60.43	$1,026	14.7%	$923,988
Selected Option: Post-Stratification Extrapolation								
Low Estimate	6	1.08	17.2	18.61	$28.11	$523	9.8%	$187,123
High Estimate	6	1.08	17.2	18.61	$60.43	$1,125	14.7%	$601,976

Source: U.S. EPA analysis

15.2.3 Wildlife Viewing

EPA expects that water quality improvements from the MP&M regulation will decrease the uptake of pollutants through aquatic food chains. These changes are expected to increase the health and reproductive success of sensitive wildlife species that feed on fish and other aquatic organisms. In particular, **Piscivorous** (i.e., fish-eating) bird species such as the osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), great blue heron (*Ardeidae herodias*), mergansers (*Merginae* sp.), and cormorants (*Phalacrocorax* sp.) will benefit from increased numbers, size, and health of forage fish. Increased food and lower pollutant levels in fish flesh will improve reproduction in these birds, leading to healthier and larger bird populations. Reducing conventional pollutant loadings will also improve visual aesthetics, thereby enhancing wildlife viewing and other near-water-based recreation experiences, such as photography, camping, picnicking, and waterfowl hunting (hereafter, this discussion refers to all of these activities as "wildlife viewing").

As with the recreational fishing analysis, EPA assumes that the expected welfare gain for consumers of viewing activities is a function of changes in the overall quality of all recreational opportunities available to each consumer. Consumers of water-based recreation residing in the counties abutting MP&M reaches are therefore likely to benefit from improved recreational opportunities whether or not they actually visit an MP&M reach.

EPA estimated wildlife viewing benefits using an approach similar to that used in estimating recreational fishing benefits. EPA estimated:

- the number of wildlife viewing days on benefiting reaches;
- the baseline value of wildlife viewing for each benefiting reach; and
- changes in wildlife viewing value, using values from the available surface water valuation studies.

a. Number of wildlife viewing days

EPA calculated the annual number of person-days of wildlife viewing for each benefiting reach using a two-step approach:

❖ ***Participating population***

The analysis of the NDS data showed that participants in viewing activities travel from 16 to 117 miles to their destination, with an average one-way travel distance of 34 miles.[16] EPA therefore assumes that improvements in recreational opportunities will benefit only recreational users residing within the counties abutting MP&M reaches. EPA estimated the population participating in viewing activities using the number of water-based recreation consumers residing in the counties traversed by benefiting reaches using the following steps:

- estimate resident populations in the counties traversed by the benefiting reaches using Census data;
- calculate the number of wildlife viewing participants based on the percent of the population engaged in wildlife viewing activities;
- estimate the percentage of individuals that participate in wildlife viewing in each state using NDS data. The total state population participating in wildlife viewing ranges from 8.6 percent in New Mexico to 44.4 percent in Maine; and
- adjust the number of wildlife viewing participants within the affected county based on the ratio of the affected reach length to the number of total reach miles in the affected county to calculate the population potentially benefiting from the rule.[17,18]

❖ ***Average number of viewing days***

Recreators generally participate in wildlife viewing several times a year. The Agency used NDS data on the number of wildlife viewing trips to estimate the average number of user days in each state. The NDS data show that the number of wildlife viewing trips in the 48 states range from 1.8 days per user in South Dakota to 24.2 days per user in Mississippi.[19]

EPA multiplied the number of wildlife viewing consumers by estimates of the average number of days per user in each state to estimate the annual number of user days for each benefiting MP&M reach.

b. Baseline value of wildlife viewing

EPA estimated the baseline value of wildlife viewing for the benefiting reaches based on the estimated annual person-days calculated in subsection (a) above and the estimated value per person-day of wildlife viewing.

EPA used two recreational activity valuation studies (Bergstrom and Cordell (1991) and Walsh et al. (1992)) to calculate the net economic values per wildlife viewing day. These studies estimate net benefit values for four recreational activities: wildlife viewing, waterfowl hunting, camping, and picnicking. Based on the two studies, EPA developed an average per-day value for three of the four activities.[20] EPA's MP&M benefits analysis uses the lowest average benefit value, $22.73, for the low estimate of wildlife viewing benefits and the highest average value, $28.73, for the high estimate. Table 15.5 presents information on the relevant values reported in these studies.

Using facility sample weights and summing over all benefiting reaches provides the total baseline value of wildlife viewing for MP&M reaches that EPA expects to benefit by eliminating pollutant concentrations in excess of AWQC limits.

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[16] These estimates exclude outliers.

[17] Information in EPA's Reach File 1 indicates that the ratio of affected reach length to the total number of reach miles within a county ranges from 0.02 to 0.39.

[18] This analysis assumes that recreation activities among residents of the counties affected by MP&M discharges are distributed evenly across all reach miles within those counties.

[19] See Chapter 21 for details on the NDS data.

[20] EPA excluded the per-day value of waterfowl hunting ($55.53) from the activities included in this analysis, because this activity is limited to designated hunting areas only.

Table 15.5: Baseline Values of Wildlife Viewing

Recreational Activity	Per-day Value (2001$)[a]		Average Per-day Value (2001$)
	Bergstrom and Cordell (1991)[b]	Walsh et al. (1992)[c]	
Camping	$27.10	$30.38	$28.73
Picnicking	$18.46	$27.00	$22.73
Near-water Activities	$20.07	$34.59	$27.33
Range of above			$22.73 - $28.73

[a] Original study values were adjusted to 2001 dollars based on the relative change in CPI from 1987 to 2001.
[b] Study location: various U.S. locations. Estimating approach: meta-analysis of TC studies.
[c] Study location: various U.S. locations. Estimating approach: meta-analysis of contingent valuation (CV) and TC studies.

Source: U.S. EPA analysis

c. Changes in wildlife viewing value

EPA selected a subset of the candidate benefits transfer studies discussed in Section 15.2.1 to estimate changes in water resource value to wildlife viewers due to the MP&M rule. The four selected studies include Tudor et al. (2002), Desvousges et al. (1987), Lant and Roberts (1990), and Farber and Griner (2000)[21]. Table 15.6 compiles information on the baseline values of wildlife viewing, values of changes in water quality, and percentage change in values reported or implied by these studies.

[21] The remaining four studies value changes in the value recreational fishing only.

Table 15.6: Studies Estimating Changes in Value of Wildlife Viewing

Study	Water Quality Change Valued	Baseline Value of Wildlife Viewing (2001$)	Value of Water Quality Change (2001$)	Value of Change as % of Baseline	Type of Benefits Included
Desvousges et al. (1987)	Improvement from "boatable" to "fishable"	$22.8 - $28.7 per trip [a]	$5.00 per trip [b]	17.4% - 22.0%	Recreational and nonuse values to users
Lant and Roberts (1990)	Improvement from "fair" to "good"	$22.8 - $28.7 per trip [a]	$8.60 per trip [c]	29.9% - 37.8%	Recreational and nonuse values to users
Farber and Griner (2000)	Improvement from "moderately polluted" to "unpolluted"	$22.8 - $28.7 per trip [a]	$3.33 - $5.69 per trip [d]	11.6% - 25.0%	Recreational and nonuse values to users
Tudor et al. (2002)	Elimination of AWQC exceedances	$77.99 per trip [e]	$0.60 per trip	0.77%	Recreational use values to users
Average percentage change (based on the above studies) [f]				14.9% - 21.3%	

[a] Based on the range of median values for a near-water recreation day (updated to 2001 dollars) reported in Walsh et al. (1992) and Bergstrom and Cordell (1991) (see Table15.5).
[b] Based on the value of water quality improvement of $36.79 per person per year (updated from 1987 dollars reported in Desvousges et al.) divided by the average number of near-water recreation days per year in Pennsylvania (7.37 days, NDS, 1993).
[c] Based on the value of water quality improvement of $57.79 per year (updated from 1990 dollars) reported in Lant and Roberts divided by the average number of near-water recreation days per year in Iowa and Illinois (9.58 and 5.04 days, NDS, 1993).
[d] Based on the value of water quality improvements ranging from $24.55 to $41.93 per person per year reported in Farber and Griner (2000) divided by the average number of near-water recreation days per year in Pennsylvania (7.37 days, NDS, 1993).
[e] The baseline value of viewing is based on the estimated mean value of water resources for wildlife viewers reported by Tudor et al. (2002). The estimated median value of recreational fishing is $82.77. These values were derived from a September 23, 2002 analysis.
[f] EPA took a simple mean of lower- and upper-bound estimates from the four studies to calculate a range of percentage changes in the wildlife viewing value from improved water quality conditions. When only one value is available from the study (i.e., Tudor et al., 2002), EPA used this value in calculating both the lower- and upper-bound estimates.

Source: U.S. EPA analysis

This analysis uses the change of 14.9 percent for the low benefits estimate and 21.3 percent for the high benefits estimate to calculate benefits from reduced MP&M facility discharges to users of water-based recreation. These values represent the average of the low and high values, respectively, estimated in the four studies.

Table 15.7 below summarizes the results of EPA's wildlife viewing benefits analysis.

Table 15.7: Summary of Wildlife Viewing Benefits (2001$)								
	Number of Benefiting Reaches	Participating Population (millions)	Ave. Number of Viewing Days	Total Viewing Days (millions)	Baseline Value/ Rec. Day	Total Baseline Value ($ millions)	% Change in Value	Benefit from MP&M
Selected Option: Traditional Extrapolation								
Low Estimate	9	3.12	7.5	23.52	$22.73	$535	14.9%	$185,172
High Estimate	9	3.12	7.5	23.52	$28.73	$676	21.3%	$334,315
Selected Option: Post-Stratification Extrapolation								
Low Estimate	6	3.17	7.5	23.91	$22.73	$544	14.9%	$120,639
High Estimate	6	3.17	7.5	23.91	$28.73	$687	21.3%	$217,805

Source: U.S. EPA analysis.

15.2.4 Recreational Boating

Improvements in water quality from the final MP&M rule may enhance recreational boating by (1) providing more opportunities for companion activities (e.g., fishing and wildlife viewing) and (2) improving visual aesthetics. EPA assumes that the expected welfare gain for boaters is a function of changes in the overall quality of all recreational opportunities available to each boater on a given day.

This analysis estimates recreational boating benefits the same way as recreational fishing and wildlife viewing benefits. The analysis estimates:

- the number of recreational boating days on benefiting reaches,
- the baseline value of boating for each benefiting reach, and
- changes in recreational boating value.

a. Number of recreational boating days

EPA calculated the annual number of recreational boating days for each benefiting reach using two steps:

❖ ***Participating population***

The analysis of the NDS data showed that boaters travel from 10 to 108 miles to their destination, with an average one-way travel distance of 32 miles.[22] This analysis therefore considers only boaters residing in the counties abutting MP&M reaches. EPA estimated the number of boaters residing in the counties traversed by benefiting reaches by combining information from Census data and NDS data on the proportion of individuals participating in boating in each state. The percent of the total state population in the 48 states participating in boating ranges from 8.0 percent in Colorado to 28.7 percent in Washington. EPA further adjusted the number of boaters likely to use MP&M reaches within the affected county based on the ratio of the affected reach length to the number of total reach miles in the affected county.[23]

[22] These estimates exclude outliers.

[23] See section 13.1.1 for detail.

❖ ***Average number of boating days***

People using benefiting reaches for boating generally participate in this activity several times per year. The NDS data show the number of boating trips in the 48 states ranging from 3.2 days per user in New Hampshire to 14.6 days per user in Colorado.

EPA estimated the annual number of user days for recreational boating activities by multiplying the number of boaters by the average number of boating days per user in each state.

b. Baseline value of boating

EPA estimated the baseline value of boating on benefiting reaches using the estimated annual person-days of boating per reach and estimated values per person-day of various types of boating. EPA calculated a range of net economic values per recreation day of boating based on studies by Bergstrom and Cordell (1991) and Walsh et al. (1992). Mean net benefit values for motorized and non-motorized boating are $37.30 to $59.26 in 2001 dollars. Table 15.8 compiles information on the relevant values reported in these studies.

Table 15.8: Baseline Values of a Boating Day

Recreational Activity	Per-day Value (2001$)[a]		Average Per-day Value (2001$)
	Bergstrom and Cordell (1991)[b]	Walsh et al. (1992)[c]	
Motorized	$25.43	$49.18	$37.30
Non-motorized	$42.67	$75.85	$59.26
Boating (any type)			$37.30 - $59.26

[a] Original study values were adjusted to 2001 dollars based on the relative change in CPI from 1987 to 2001.
[b] Study location: various U.S. locations. Estimating approach: meta-analysis of TC studies.
[c] Study location: various U.S. locations. Estimating approach: meta-analysis of CV and TC studies.

Source: U.S. EPA analysis

Weighting by facility sample weights and summing over all benefiting reaches provides a total baseline value of boating for MP&M reaches expected to benefit by eliminating pollutant concentrations in excess of AWQC limits.

c. Changes in recreational boating values

The Agency used the same four studies discussed in Section 15.2.3 to calculate the change in per-day boating value as a result of water quality improvements. EPA expressed this change as a percentage of the baseline value. Table 15.9 compiles information on the baseline values of boating, values of changes in water quality, and percentage change in boating values reported or implied by these studies.

Table 15.9: Studies Estimating Changes in Value of Recreational Boating

Study	Water Quality Change Valued	Baseline Value of Boating (2001$)	Value of Water Quality Change (2001$)	Value of Change as % of Baseline	Type of Benefits Included
Desvousges et al. (1987)	Improvement from "boatable" to "fishable"	$37.30 - $59.26 per trip [a]	$3.92 per trip [b]	6.6% -10.5%	Recreational and nonuse values to users
Lant and Roberts (1990)	Improvement from "fair" to "good"	$37.30 - $59.26 per trip [a]	$7.91 per trip [c]	13.3% -21.2%	Recreational use values to users and nonusers
Farber and Griner (2000)	Improvement from "moderately polluted" to "unpolluted"	$37.30 - $59.26 per trip [a]	$2.62 - $4.48 per trip [d]	4.4%-12.0%	Recreational and nonuse values to users
Tudor et al. (2002)	Elimination of AWQC exceedances	$106.60 per trip [e]	$1.78 pr trip	1.67%	Recreational values for users
Average percentage change (based on the above studies) [f]				6.5% - 11.4%	

[a] Based on the average value for a boating day (updated to 2001 dollars) reported in Walsh et al. (1992) and Bergstrom and Cordell (1991).
[b] Based on the value of water quality improvement of $36.79 per person per year (updated from 1987 dollars) reported in Desvousges et al. divided by the average number of boating days per year in Pennsylvania (9.37 days, NDS, 1993).
[c] Based on the value of water quality improvement of $57.79 per person per year (updated from 1990 dollars) reported in Lant and Roberts divided by the average number of boating days per year in Iowa and Illinois (9.58 and 5.04 days, NDS, 1993).
[d] Based on the value of water quality improvements ranging from $24.55 to $41.93 per person per year reported in Farber and Griner (2000) divided by the average number of boating days per year in Pennsylvania (9.37 days, NDS, 1993).
[e] The baseline value of boating is based on the estimated mean value of water resources for boaters reported by Tudor et al. (2002). The estimated median value of recreational boating is $112.55. These values were derived from a September 23, 2002 analysis.
[f] EPA took a simple mean of lower- and upper-bound estimates from the four studies described to calculate a range of percentage changes in the recreational boating value from improved water quality. When only one value is available from the study (i.e., Tudor et al., 2002), EPA used this value in calculating both the lower- and upper-bound estimates.

Source: U.S. EPA analysis

This analysis uses the change of 6.5 percent for the low benefits estimate and 11.4 percent for the high benefits estimate to calculate benefits to boaters from reduced MP&M facility discharges. These values represent the average of the low and high values, respectively, estimated in the four studies.

Table 15.10 summarizes the results of EPA's recreational boating benefits analysis.

Table 15.10: Summary of Recreational Boating Benefits (2001$)								
	Number of Benefiting Reaches	Participating Population (millions)	Ave. Number of Boating Days	Total Boating Days (millions)	Baseline Value/ Rec. Day	Total Baseline Value ($ millions)	% Change in Value	MP&M Benefits
Selected Option: Traditional Extrapolation								
Low Estimate	9	2.53	8.3	21.06	$37.30	$786	6.5%	$114,111
High Estimate	9	2.53	8.3	21.06	$59.26	$1,249	11.4%	$316,078
Selected Option: Post-Stratification Extrapolation								
Low Estimate	6	2.57	8.4	21.47	$37.30	$801	6.5%	$74,343
High Estimate	6	2.57	8.4	21.47	$59.26	$1,272	11.4%	$205,924

Source: U.S. EPA analysis.

15.2.5 Nonuse Benefits

EPA estimated changes in nonuse values for this analysis because nonuse value is a sizeable portion of the total value of water resources. Individuals who never visit or otherwise use a natural resource may still be affected by changes in its status or quality. Empirical estimates indicate that such "nonuse values" may be substantial for some resources (Harpman et al., 1993; Fisher and Raucher, 1984; Brown, 1993). Most studies have found that nonuse values exceed use values. Brown reviewed 31 CV studies in which both use and nonuse values were estimated, and calculated the ratio of nonuse values to use values (Brown, 1993). The goal of Brown's study was to assess consistency of ratios of use to nonuse value and to develop a basis for obtaining a rough estimate of nonuse value, and therefore total values, for the many studies that measured only use values. His 31 estimated ratios range from 0.1 to 10, with the median ratio of 1.92. The ratios of nonuse to use values reported by Brown for the studies that valued environmental improvements in water resources range for users of those resources from 0.85 to 2.56. The estimated average ratio is 1.57. That is, for every dollar of annual use-benefit value to users of the subject environmental resource, the annual nonuse value to resource users for the subject environmental resource is $1.57.

Carson and Mitchell suggested that nonuse benefits account for 19 to 39 percent of total WTP values for water quality improvements depending on the definition of nonuse values (Carson and Mitchell, 1993). The ratio of nonuse to use value ranges from one-fourth to two-thirds based on the Carson and Mitchell study (1993). Fisher and Raucher (1984) found that nonuse benefits comprise one-half of recreational use benefits.

EPA used findings from the Fisher and Raucher (1984) study in which nonuse values are estimated to be equal to 50 percent of use values to estimate nonuse benefits from the final MP&M regulation. The method has long been used by EPA as a pragmatic alternative to omitting nonuse values entirely. EPA acknowledges that this method is crude and nonuse values estimated by the 50 percent of use value approach are quite low given the applicable literature discussed above.

The Agency estimates that nonuse benefits from the final MP&M rule will range from $293,252 to $787,190 and from $191,053 to $512,852, based on the traditional and post-stratification extrapolation, respectively.

15.3 Summary of Recreational Benefits

EPA assumes that eliminating concentrations of MP&M pollutants in excess of AWQC limits will achieve water quality protective of aquatic life and human health. This improved water quality then generates benefits for both users and nonusers of water-based recreation. These benefits can be seen as an increase in the value of each day spent on or near the waterway, as well as an increase in the number of days spent on or near the waterway. EPA estimated the monetary value of improved water-based recreational opportunity for the 9 discharge reaches based on the traditional extrapolation (6 reaches based on the post-stratification extrapolation) for which concentrations in excess of AWQC limits would be eliminated.

EPA first estimated the number of recreational days on benefiting reaches for each water-based activity. The Agency then calculated the baseline value of these activities and then calculated the percentage changes in this value stemming from water quality improvements.

EPA calculated partial benefits for reaches with reduced numbers of AWQC exceedances by adjusting the percentage increase in the recreational value of these reaches. EPA made these adjustments based on the ratio of the number of AWQC exceedances eliminated post-compliance to the number of AWQC exceedances occurring at baseline.

Table 15.11 summarizes benefit estimates by recreational category for the final rule based on the traditional and post-stratification extrapolation methods. The activities considered in this analysis are stochastically independent; EPA calculated the total value of enhanced water-based recreation opportunities by summing over the three recreation categories. EPA also estimated the changes in nonuse value resulting from reduced MP&M discharges based on the ratio of use to nonuse values implied by the Fisher and Raucher study (Fisher and Raucher, 1984). Based on the traditional extrapolation, the estimated increase in nonuse value ranges from $0.29 to $0.79 million (2001$), with a midpoint value of $0.50 million (2001$). The resulting increased value of recreational activities to consumers (users and nonusers) of water-based recreation ranges from an estimated $0.59 to $1.57 million (2001$) annually. The estimated mean value of recreational benefits is $1.00 million (2001$) annually. Likewise, based on the post-stratification extrapolation, the estimated increase in nonuse value ranges from $0.19 to $0.51 million (2001$), with a midpoint value of $0.33 million (2001$). The resulting increased value of recreational activities to consumers (users and nonusers) of water-based recreation ranges from an estimated $0.38 to $1.03 million (2001$) annually. The estimated mean value of recreational benefits is $0.65 million (2001$) annually.

Tables 15.12 and 15.13 summarize benefit estimates for the 433 Upgrade Options and Proposed/NODA Option, respectively. Recreational use and nonuse benefits are almost 200 times higher under the two 433 Upgrade Options, and over 430 times higher under the Proposed/NODA Option.

Table 15.11: Estimated Recreational Benefits from Reduced MP&M Discharges (Thousands, 2001$)

Recreational Activity	Traditional Extrapolation			Post-Stratification Extrapolation		
	Low Value	Midpoint Value	High Value	Low Value	Midpoint Value	High Value
Fishing	$287	$537	$924	$187	$350	$602
Boating	$114	$203	$316	$74	$132	$206
Viewing and near-water activities	$185	$260	$334	$121	$169	$218
Total Recreational Use Benefits	$587	$1,000	$1,574	$382	$651	$1,026
Nonuse Benefits (½ of the Recreational Use Benefits)	$293	$500	$787	$191	$326	$513
Total Recreational Benefits	**$880**	**$1,500**	**$2,362**	**$573**	**$977**	**$1,539**

Source: U.S. EPA analysis.

Table 15.12: Estimated Recreational Benefits from Reduced MP&M Discharges (Thousands, 2001$)[a]

Recreational Activity	Directs + 413 to 433 Upgrade			Directs +All to 433 Upgrade		
	Low Value	Midpoint Value	High Value	Low Value	Midpoint Value	High Value
Fishing	$28,713	$53,703	$92,369	$29,052	$54,337	$93,460
Boating	$36,511	$64,854	$101,134	$36,652	$65,103	$101,523
Viewing and near-water activities	$56,584	$79,434	$102,158	$56,657	$79,536	$102,290
Total Recreational Use Benefits	$121,808	$197,990	$295,661	$122,360	$198,976	$297,272
Nonuse Benefits (½ of the Recreational Use Benefits)	$60,904	$98,995	$147,831	$61,180	$99,488	$148,636
Total Recreational Benefits	**$182,712**	**$296,986**	**$443,492**	**$183,541**	**$298,464**	**$445,908**

[a] Based on the Traditional Extrapolation.

Source: U.S. EPA analysis.

Table 15.13: Estimated Recreational Benefits from Reduced MP&M Discharges (Thousands, 2001$)[a]

Recreational Activity	Proposed/NODA Option[b]		
	Low Value	Midpoint Value	High Value
Fishing	$53,897	$100,805	$173,386
Boating	$75,847	$134,724	$210,089
Viewing and near-water activities	$140,623	$197,410	$253,884
Total Recreational Use Benefits	$270,366	$432,939	$637,360
Nonuse Benefits (½ of the Recreational Use Benefits)	$135,183	$216,469	$318,680
Total Recreational Benefits	**$405,550**	**$649,408**	**$956,040**

[a] Based on the Traditional Extrapolation.
[b] The estimated recreational benefits of the Proposed/NODA Option are not directly comparable to the final option alternatives. The total number of facilities reported for the Proposed/NODA Option analysis differs from the facility count reported for the final rule and the two upgrade options. After deciding in July 2002 not to consider the NODA option as the basis for the final rule, EPA performed no more analysis on the NODA option, including not updating facility counts and related analyses for the change in subcategory and discharge status classifications.

Source: U.S. EPA analysis.

15.4 Limitations and Uncertainties Associated with Estimating Recreational Benefits

EPA assessed recreational benefits in terms of reduced occurrence of pollutant concentrations exceeding acute and chronic toxic effect levels for aquatic species. EPA also attached a monetary value to ecological improvements expected to result from the MP&M regulation, in the form of the increased value of three water-based recreation activities recreational fishing, wildlife viewing, and boating plus the increase in nonuse value. The estimated increase in value detailed in this chapter constitutes only a partial measure of the value to society of improving aquatic habitats and aquatic life. This benefits analysis is limited because it ignores improvements to recreational activities other than fishing, boating, and wildlife viewing (e.g., swimming), as well as non-recreational benefits, such as increased assimilative capacity and improvements in the taste and odor of the affected waters.

The methodologies used to assess ecological benefits also involved significant simplifications and uncertainties, whose combined effect on the estimated benefits is not known. Estimated economic values may be under- or overestimated. Some of these simplifications and uncertainties also apply to the human health benefits analysis, and have been discussed at length in the previous chapter, including those associated with:

- developing the sample of MP&M facilities analyzed in the EEBA,
- estimating in-waterway concentrations of MP&M pollutants,
- considering background concentrations of MP&M pollutants, and
- considering downstream effects.

Table 15.14 summarizes the additional elements of uncertainty that are specific to the recreational benefits analysis.

Table 15.14: Key Omissions, Biases, and Uncertainties in the Analysis for Improved Recreational and Nonuse Benefits

Assumption/Limitation	Direction of Impact on Benefit Estimates
Scope of Recreational Benefits Analysis	
Only the receiving reach itself is estimated to provide benefits.	(-) Water quality in reaches downstream of the reaches affected by MP&M discharges may also improve, generating additional benefits to society. Excluding these benefits from the analysis biases benefits estimates downward.
Only recreational users living in the counties abutting MP&M reaches are assumed to benefit from water quality improvements due to the MP&M rule.	(-) The analysis underestimates the total value of benefits from the MP&M regulation because it does not account for people's WTP for water quality improvements to distant water bodies. For example, economic values for improving nationally-significant water bodies (e.g., Great Lakes, Chesapeake Bay, Long Island Sound) are likely to be substantial at a regional level or even nationwide.
The analysis of recreational fishing ignores effects that occur in secondary industries.	(-) The analysis of recreational benefits ignores potential economic effects on tourism industries stemming from improved recreational opportunities. Improved recreational fishing may have a positive effect on industries supplying bait, tackle, charter boats, etc. An increase in consumer demand for boating may have positive effects on industries such as boat construction, sales, rentals, boating equipment, marinas, racing activities, etc. Improvements in wildlife viewing and near-water recreation opportunities may benefit industries involved in providing other recreational opportunities, such as tours, books, binoculars, etc.
The analysis of recreational benefits ignores changes in the value of water-based recreational activities other than fishing, wildlife viewing, and boating (e.g., swimming or waterskiing).	(-) The estimate of recreational benefits is incomplete because it includes only a subset of recreational activities (i.e., fishing, wildlife viewing, and boating) for which society may value improved aquatic habitat. It ignores changes in value for other water-based recreational activities, such as swimming or waterskiing. In addition, the analysis did not consider other changes in the affected reaches, such as improved taste and odor.

Table 15.14: Key Omissions, Biases, and Uncertainties in the Analysis for Improved Recreational and Nonuse Benefits

Assumption/Limitation	Direction of Impact on Benefit Estimates
Extrapolating from sample facility results to national results is based on the sample facility weights	(?) This extrapolation technique is not ideal and introduces uncertainty into the analysis. Facility sample weights are based on facility size and type of industry. These weights do not necessarily account for the frequency benefit pathway characteristics in the MP&M facility universe. Therefore benefit estimates may suffer from uncertainties associated with the extrapolation method. For example, a sample facility may have a significant impact on benefit estimates if it is more likely to be located in a densely populated area, such as a facility located in Cleveland, Ohio, or a facility discharging in Long Island Sound, than the facilities it represents. The opposite may also be true. To improve accuracy of the national benefit estimates, EPA used an alternative extrapolation method (i.e., post-stratification extrapolation). This method relies on adjusted sample facilities weights that account for the distribution of benefit pathway characteristics, including water body type and population size, in the MP&M facility universe. Appendix G summarizes this extrapolation approach.
Congestion Externalities	(+) Recreational benefits associated with water quality improvements can be eroded by congestion if policies greatly increase the number of participants. This can be particularly problematic when policies affect geographically scattered sites, so that there is considerable switching to the improved site from substitute sites. Congestion may be a lesser problem for national regulations that might affect the total number of recreation days and the overall value of recreational opportunities, but are less likely to have a large effect on industrial sites relative to its substitutes.
Benefits Transfer	
The waters assessed by local-level studies are not necessarily nationally representative.	(?) The studies selected came from the Midwest and the Northeast. As a result, the resources valued, as well as respondent preferences, may not be representative of the rest of the country.
Types of water quality changes expected from the MP&M rule may differ from the water quality changes considered in the original studies.	(?) The types of water quality changes expected from the MP&M regulation are only roughly comparable with the majority of water quality changes considered in the original studies (Tudor et al. is the only exception). Due to the paucity of available studies, the Agency made simplifying assumptions to "map" the water quality changes valued in the original studies onto those expected from the rule. Although these assumptions are likely to increase uncertainty associated with recreational benefits estimates, the direction of bias is not known.
Compatibility of time periods considered in the original studies and in the analysis of MP&M costs and benefits.	(+) Most studies considered in the benefits transfer analysis did not specify payment periods. The scenario in the Farber and Griner (2000) paper asked for payments for the next five years. This scenario implies that five years of pollution control will result in permanent water quality changes. The analysis of the MP&M regulation assumes that pollution control continues over 15 years and that water quality improvements depend on continued operation of the water pollution controls. EPA therefore chose the annual WTP values presented in the paper, as opposed to the total value paid over five years, annualized over the 15 years considered in the cost analysis. This assumption may result in an overestimation of the regulation's benefit. The magnitude of this error is unlikely to be significant because this study is used in combination with other surface water valuation studies.
Baseline Value of Fishery	
Converting annual WTP values to per-trip values	(+) EPA converted annual WTP values reported in the three CV studies used in this analysis to per-trip values by dividing seasonal welfare gain per user reported in each CV study by the average number of fishing, boating, or viewing days in a given state. This calculation implies that every individual participates in only one activity, which may not be the case. This implication may result in an overestimation of the per-trip welfare gain, and, consequently, an overestimation of total recreational benefits from the final rule.

Table 15.14: Key Omissions, Biases, and Uncertainties in the Analysis for Improved Recreational and Nonuse Benefits

Assumption/Limitation	Direction of Impact on Benefit Estimates
This analysis estimates the baseline value of the fisheries at locations across the country using a range of values for all types of fisheries.	(?) Site-specific fisheries may have higher or lower baseline values, and thus, higher or lower benefits from reduced MP&M discharges.
The total number of recreational person-days in the counties abutting MP&M reaches is evenly distributed across all reach miles in these counties.	(+) This method for estimating the number of recreational users potentially affected by water quality improvements from the final regulation accounts for the quantity but not quality of potential recreational opportunities available to recreational users. There may be important substitute sites in or outside the counties abutting MP&M reaches. Ignoring recreationally important substitute sites may result in overestimation of benefits from the final regulation. Ideally the analysis would consider recreational importance of both sites affected by MP&M discharges and substitute sites.
Nonuse Values	
Nonuse values are estimated as one-half of recreational use benefits.	(?) It is unknown what bias estimating nonuse values based on recreational use values has on benefits.
Overall Impact on Benefits Estimates	**(?)**

\+ Potential overestimate.
? Uncertain impact.
\- Potential underestimate.

Source: U.S. EPA analysis.

GLOSSARY

1Q10: the lowest one-day average flow with a recurrence interval of ten years.

7Q10: the lowest consecutive seven-day average flow with a recurrence interval of ten years.

ambient water quality criteria (AWQC): published and periodically updated by the EPA under the Clean Water Act. The criteria reflect the latest scientific knowledge on the effects of specific pollutants on public health and welfare, aquatic life, and recreation. The criteria do not reflect consideration of economic impacts or the technological feasibility of reducing chemical concentrations in ambient water. The criteria serve as guides to states, territories, and authorized tribes in developing water quality standards and ultimately provide a basis for controlling discharges or releases of pollutants into our nation's waterways. AWQC are developed for two exposure pathways: ingestion of the pollutant via contaminated aquatic organisms only, and ingestion of the pollutant via both water and contaminated aquatic organisms.

benefiting reaches: reaches where the MP&M rule is expected to eliminate existing AWQC exceedences. These receiving waters are likely to experience significant water quality improvements as a result of the reduced MP&M discharges. A reach is considered to benefit if at least one AWQC exceedance is eliminated due to reduced MP&M discharges.

benefits transfer: involves the application of value estimates, functions, and/or models developed in one context to address a similar resource valuation question in another context. Often a meta-analysis is undertaken where benefits estimates based on existing studies are used to develop new estimates which are applicable to the scenario under consideration. This process accounts for relevant differences in study characteristics, such as the quality of environmental resource, the environmental change considered, and the user population being investigated.

contingent valuation (CV): directly asks people what they are willing to pay for a benefit and/or willing to receive in compensation for tolerating a cost through a survey or questionnaire. Personal valuations for increases or decreases in the quantity of some good are obtained contingent upon a hypothetical market. The aim is to elicit valuations or bids that are close to what would be revealed if an actual market existed.

conventional pollutants: biological oxygen demand (BOD), total suspended solids (TSS), oil and grease (O&G), pH, and anything else the Administrator defines as a conventional pollutant.

dissolved oxygen (DO): oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatment are generally designed to ensure adequate DO in waste-receiving waters. (http://www.epa.gov/OCEPAterms/dterms.html)

Metal Products and Machinery (MP&M): industry includes facilities that manufacture, rebuild, and maintain metal parts, products, or machines.

National Demand Study (NDS): U.S. EPA and the National Forest Service conducted the National Demand Survey for Water-Based Recreation in 1993. The survey collected data on demographic characteristics and water-based recreation behavior using a nationwide stratified random sample of 13,059 individuals aged 16 and over.

nonconventional pollutant: catch-all category that includes everything that is not classified as a priority pollutant or a conventional pollutant.

piscivorous: feeding preferably on fish.

priority pollutant (PP): 126 individual chemicals that EPA routinely analyzes when assessing contaminated surface water, sediment, groundwater, or soil samples.

toxic pollutants: EPA's Office of Water narrowly defines a toxic pollutant as one of 126 priority pollutants. This definition is not completely synonymous with pollutants that have a "toxic" effect. Many nonconventional pollutants may also be hazardous to aquatic life and human health.

"toxic" pollutant: any pollutant that has an adverse effect on aquatic life or human health.

travel cost (TC) model: derives values by evaluating expenditures of recreators. Travel costs are used as a proxy for price in deriving demand curves for the recreation site. (http://www.damagevaluation.com/glossary.htm)

U.S. Fish and Wildlife Service (FWS): the principal federal agency responsible for conserving, protecting, and enhancing fish, wildlife, and plants and their habitats for the continuing benefit of the American people. (http://www.fws.gov/r9extaff/pafaq/fwsfaq.html)

willingness-to-pay (WTP): maximum amount of money one would give to buy some good. (http://www.damagevaluation.com/glossary.htm)

ACRONYMS

1Q10: the lowest 1-day average flow with a recurrence interval of 10 years
7Q10: the lowest 7-day average flow with a recurrence interval of 10 years
AWQC: ambient water quality criteria
CV: contingent valuation
DO: dissolved oxygen
FWS: U.S. Fish and Wildlife Service
MP&M: Metal Products and Machinery
NDS: National Demand Study
TC: travel cost
WTP: willingness-to-pay

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Chapter 16: POTW Benefits

INTRODUCTION

CHAPTER CONTENTS

The final rule only regulates direct dischargers. Therefore, the selected option does not affect POTW operations. For the alternative policy options that consider both direct and indirect dischargers, EPA evaluated two categories of productivity benefits for ***publicly-owned treatment works (POTWs)***:

- reduced ***interference*** with the operations of POTWs, and
- reduced contamination of sewage sludge (i.e., biosolids) at POTWs that receive discharges from MP&M facilities.

Interference with POTW processes occurs when high levels of toxics, such as metals or cyanide, kill bacteria required for wastewater treatment processes. The removal of these pollutants would eliminate the need for extra labor and materials to maintain POTW operations.

Toxic priority and nonconventional pollutants may also pass through a POTW and contaminate sludge generated during primary and secondary wastewater treatment.[1] POTW treatment of wastewater with reduced pollutant concentrations translates into cleaner sludge, which can be disposed of using less expensive and more environmentally benign methods. In some cases, cleaner sludge may have agricultural applications, which would generate additional resource conservation benefits.

Some MP&M pollutants that pass through a POTW and contaminate sludge are not currently subject to sewage sludge pollutant concentration limits. The alternative policy options would reduce concentrations of these pollutants in sewage sludge as well, which may translate into reduced environmental and human health risks. EPA did not estimate the reduced risk attributable to the reduction of these pollutants.

Wastewater from MP&M facilities also contains ***hazardous air pollutants (HAPs)***. These pollutants may represent unacceptable health risks to POTW workers if released into the air at high enough concentrations during the wastewater treatment cycle. This reduction in pollutants may translate into health benefits to POTW workers and those living near POTWs.

The remaining sections of this chapter present methodology for estimating benefits to the receiving POTWs from reducing pollutants in the wastewater of indirect MP&M dischargers. As noted above, the final option does not affect POTW operations since it regulates direct dischargers only. For the alternative options that consider both direct and indirect dischargers, EPA evaluated two benefits measures associated with MP&M pollutants: (1) the reduction in pollutant interference at POTWs; and (2) pass-through of pollutants into the sludge, which limits options for POTW disposal of sewage sludge.

[1] The term sewage sludge, also called biosolids, is often shortened to sludge throughout this chapter for simplicity.

16.1 Reduced Interference with POTW Operations

High levels of some MP&M pollutants (such as metals, chlorobenzene, polyaromatic hydrocarbons, and oil and grease) can kill bacteria that are required for the wastewater treatment process (U.S. EPA, 1987). POTWs affected by such "inhibition problems" may incur extra labor and materials costs to maintain system operations. As a partial measure of the economic benefits resulting from the alternative regulatory options, EPA estimated the extent to which reduced MP&M discharges would decrease pollutant concentrations to below POTW ***pollutant inhibition values***, using the following steps:

- estimate the baseline and post-compliance ***influent concentrations*** for each POTW receiving discharges from MP&M facilities, based on annual pollutant loadings from the MP&M facility, the number of POTW operating days per year, and the gross volume of influent;

- compare baseline and post-compliance influent concentrations with available inhibition levels (see Table I.5 in Appendix I); and

- estimate the change in the number of POTWs in which influent concentrations of MP&M pollutants exceed POTW inhibition values.

Adverse effects on POTW operations, including inhibition of ***microbial degradation***, are likely when influent concentrations of one or more pollutants exceed an inhibition value. EPA estimated influent concentrations in excess of POTW inhibition values for the sample facilities for the baseline and the alternative regulatory options. Results of this analysis are presented in Appendix I of this report. Eliminating the exceedances will result in operating cost savings to POTWs. EPA has not estimated a monetary value for this benefit, however, due to data limitations.

The final rule only regulates direct dischargers. Therefore, the selected option does not affect POTW operation. For the alternative policy options that consider both direct and indirect dischargers, EPA estimated that 51 POTWs had influent concentrations in excess of biological inhibition values for one or more pollutants under the baseline conditions corresponding to the 433 Upgrade Options. This represents 0.3% of the over 16,000 POTWs operating nationwide. (Table I.12 in Appendix I provides detailed information on pollutants exceeding POTW inhibition criteria.) Both upgrade options would eliminate exceedances of POTW inhibition criteria in 21 POTWs.

EPA's analysis finds that influent concentrations in 293 POTWs exceed biological inhibition values for one or more pollutants under the Proposed/NODA Option. The Proposed/NODA Option would eliminate inhibition criteria exceedances in 156 of the affected POTW.[2]

POTWs may impose local limits to prevent inhibitions. If local limits are in place, the estimated reduction in potential inhibition problems at the affected POTWs may be overstated. In this case, however, the estimated social cost of the MP&M regulation is also overstated.

16.2 Assessing Benefits from Reduced Sludge Contamination

16.2.1 Data Sources

The analysis of POTW benefits from improved sludge quality draws on several data sources. The §308 POTW Surveys provide most of the required information. EPA collected information from 147 POTWs representing a 98 percent response rate to the 150 surveys that were mailed. EPA also used the §308 survey of MP&M facilities. The two data collection efforts were not designed to provide a match between the MP&M sample facilities and the POTWs to which they discharge. EPA obtained a significant amount of information from the POTW Surveys, but had substantially less information on the POTWs that receive discharges from the MP&M facilities. To address this data limitation, EPA used the POTW Survey data to infer

[2] The total number of facilities reported for the Proposed/NODA Option analysis differs from the facility count reported for the final rule and the upgrade options (Directs + 413 to 433 Upgrade Option, Directs + All to 433 Upgrade Option). After deciding in July 2002 not to consider the NODA option as the basis for the final rule, EPA did not perform any more analyses on the NODA option -- including not updating facility counts and related analyses for the change in subcategory and discharge status classifications.

information on the key factors that are likely to influence choice of sewage sludge use and disposal practices for the POTWs receiving discharges from the MP&M facilities.

The POTW Survey contains three sections. Section 1 provides general information on POTW location and size. Section 2 provides data on the cost of administering pre-treatment programs (see Appendix F). Section 3 contains data on the cost of treating and disposing of sewage sludge and provides new and more consistent data for analyzing the effect of reduced pollutant loadings on sewage sludge management costs.

The POTW Survey asked for the following information:

- current sludge disposal practices;
- sludge disposal costs for one or more disposal methods;
- reasons for not using a less expensive disposal method;
- number of MP&M facilities discharging to the POTW, by flow size (less than 1 million gal/year; 1-6.25 million gal/year; greater than 6.25 million gal/year);
- total metal loadings discharged to the POTW from all sources; and
- percentage of total metal loadings attributable to MP&M facilities.

The POTW Survey was intended to address data limitations encountered in the Phase 1 analysis, particularly the inadequacy of information about POTWs that receive discharges from the MP&M sample facilities. The only information available for the Phase I analysis was POTW geographic location, influent volume, and the metals content of the discharge received from the sampled MP&M facilities. Discharges to the POTW by non-sampled MP&M facilities and by non-MP&M facilities were not known. These discharges may significantly affect sewage sludge quality, however, resulting in a discrepancy between predicted and actual pollutant concentrations in sewage sludge and the corresponding disposal practices. In addition, lack of information on the factors that may influence a POTW's decisions about sludge management practices introduced additional uncertainty in the analysis.

EPA used the POTW Survey to calculate the following parameters:

- baseline percentage of the total metal loadings to POTWs by POTW flow category attributable to MP&M facilities;
- post-compliance loading reductions for non-sampled MP&M facilities discharging to the receiving POTWs;
- costs of sewage sludge disposal practices; and
- percentage of qualifying sludge that is not beneficially used for any of the following reasons: lack of land; lower cost alternative; inability to meet ***vector*** or ***pathogen*** requirements; poor weather; stricter state standards; and other reasons.

EPA also used the data provided by the Association of Metropolitan Sewerage Agencies (AMSA) to refine its analysis of POTW benefits for the final rule. AMSA provided EPA with comments on the proposed MP&M rule and supplemented these comments with a spreadsheet database (AMSA, 2000). The database contains data from an AMSA formulated survey and covers responses from 176 POTWs, representing 66 pretreatment programs. The AMSA survey was conducted to verify data from EPA's survey of POTWs and therefore included similar, although fewer, variables compared to EPA's survey.

EPA used the results of the AMSA survey to supplement information from the MP&M POTW Survey on percentage of metal loadings contributed by MP&M facilities and the number of MP&M facilities served by POTWs. Based on the results of the joint analysis of the EPA and AMSA surveys, EPA revised the following elements of the POTW benefits methodology: (1) the number of MP&M facilities served by small, medium, and large POTWs, (2) percentage of metal loadings contributed by MP&M facilities, and (3) percentage of qualifying sludge that is not land-applied.

Finally, EPA used other data sources in this analysis, including *Handbook for Estimating Sludge Management Costs* (EPA, 1985) and *Regulatory Impact Analysis of the Part 503 Sludge Regulation* (EPA, 1993b).

16.2.2 Sludge Generation, Treatment, and Disposal Practices

a. Sludge generation

POTWs generally treat wastewater from industrial indirect dischargers along with domestic wastewater. Sludge results from primary, secondary, and advanced wastewater treatment. The extent and type of wastewater treatment determine the chemical and physical character of the sludge. Sludge may be conditioned, thickened, stabilized, and dewatered to reduce its volume.

Sludge contains five classes of components: organic matter, pathogens, nutrients, inorganic chemicals, and organic chemicals. The mix and levels of these components ultimately determine the human health and environmental impact of sludge use/disposal, and so may also dictate the most appropriate uses and disposal practices (EPA, 1993b).

Organic matter (the primary constituent of sludge) comes from human waste, kitchen waste, and stormwater runoff. Organic and inorganic chemicals in sludge come from industrial processes that discharge to municipal sewers. The concentration of inorganic pollutants in sludge, including metals, depends upon the volume and type of industrial wastes discharged to the POTW, as well as the extent and character of stormwater runoff.

b. Sludge use/disposal practices

After treatment, sludge can be used in the following ways:

- *Land Application:* Spraying or spreading on the land surface, injection below the surface, or incorporation into the soil, for soil conditioning or fertilization of crops or vegetation. Agricultural lands (pasture, range land, crops), forest lands (***silviculture***), and drastically disturbed lands (land reclamation sites) may all receive sludge;

- *Bagged Application:* Collection of sludge in containers for application to land (i.e., distribution and marketing);

- *Surface Disposal:* Disposal on land specifically set aside for this use, including surface impoundments (also called lagoons), sludge monofills (i.e., sludge-only landfills), and dedicated sites (i.e., land on which sludge is spread solely for final disposal);

- *Co-disposal:* Disposal in a ***municipal solid waste landfill (MSWL)*** or ***hazardous waste landfill***; and

- *Incineration:* Combustion of organic and inorganic matter at high temperatures in an enclosed device.

Land application and bagged application are beneficial uses of sludge. Both methods can be categorized as being "high" or "low," depending on pollutant concentrations in sewage sludge. "High" applications meet stringent limits on the total concentration of a given pollutant at a given application site. "High" sludge is exempt from meeting pollutant loading rate limits and certain record-keeping requirements. "Low" applications meet less stringent "ceiling" limits for pollutants. Ceiling limits govern whether a sewage sludge can be applied to land at all. "Low" applications require more record-keeping because POTWs must track total (cumulative) loadings applied to each given site, in addition to tracking the concentration of sludge applied at any given time.

Many POTWs use more than one use/disposal practice, which helps to maintain flexibility and avoid the capacity limitations of a single practice. The practice chosen depends on several factors, including:

- cost to prepare sludge for use/disposal;

- pollutant concentrations;

- market demand for sludge;

- cost to transport sludge to use/disposal sites;

- availability of suitable sites for land application, landfilling, or surface disposal;

- weather and other local conditions;

- allowance of a safety factor to account for unplanned or unforseen conditions;

- state environmental regulations; and

- public acceptance (EPA, 1993b).

The choice of use/disposal method is restricted by the quality of the sludge generated by the POTW. Sludge for beneficial uses must meet more stringent standards for pollutant concentrations than sludge used or disposed of in other ways. Similarly, sludge that is surface-disposed in an unlined unit generally must meet more stringent standards than sludge surface-disposed in a lined unit, disposed in an MSWL, or incinerated. Sludge disposed in a MSWL must meet more stringent standards than incinerated sludge.

Table 16.1 summarizes sludge use/disposal methods according to the number and percent of dry metric tons ***(DMT)***, based on information provided in Section 3 of the §308 POTW Survey. The information presented in this table takes into account data provided by AMSA on POTW characteristics such as POTW flow and the total amount of sludge generated by each POTW. Because the AMSA data was collected five years after the EPA POTW Survey was administered and it does not correspond to the base year of the analysis (1996), EPA did not use AMSA data to adjust the allocation of sludge to each use/disposal method category.

Table 16.1: Sludge Use/Disposal (1996) by POTWs Discharging > 2 Million Gallons/Day[a]

Use/Disposal Sub-Class	Thousand DMT	Percent of DMT
Total Beneficial Use	**2,641.2**	**39.9%**
Land Application-High	1,017.4	15.4%
Bag Application-High	339.9	5.1%
Land Application-Low	1,283.9	19.4%
Bagged Application-Low	0	0%
Total Surface Disposal	**528.2**	**8.0%**
Surface Disposal: Unlined Unit	347.2	5.3%
Surface Disposal: Lined Unit	181.0	2.7%
Co-Disposal: Municipal Landfill	**1,768.8**	**26.8%**
Incineration	**1,129.9**	**17.1%**
Unknown: Other	**543.2**	**8.2%**
All	**6,611.2**	**100.0%**

[a] The §308 POTW Survey did not collect information from POTWs discharging < 2 million gallons per day.

Source: U.S. EPA, POTW Survey and AMSA Survey (2000) on Proposed MP&M Effluent Guidelines.

As Table 16.1 shows, 39.9 percent of total sludge tons reported by respondents is used beneficially (land application and bagged application). Co-disposal in a municipal landfill is the second most frequently used disposal method, accounting for 26.8 percent of all sludge disposed in the U.S. Surface disposal in unlined and lined units, incineration, and "other" disposal methods account for 5.3 percent, 2.7 percent, 17.1 percent, and 8.2 percent of all sludge tons, respectively. No sludge was sent to a hazardous waste landfill by the POTW Survey respondents.

c. Pollutant limits and disposal options

Section 405(d) of the Clean Water Act, as amended, requires EPA to specify acceptable management practices and numerical limits for certain pollutants in sludge. The Agency published *Standards for the Use/Disposal of Sludge* (40 CFR Part 503, February 1993) to protect public health and the environment from reasonably anticipated adverse effects of pollutants in sludge (U.S. EPA, 1993a). The standards include general requirements, pollutant limits, management practices, operational standards, monitoring frequency, record-keeping, and reporting for the final use and disposal of sludge in four circumstances:

- sludge co-disposed with household waste in a MSWL;

- sludge land-applied for beneficial purposes (including bagged sludge);
- sludge disposed on land or on surface disposal sites; and
- incinerated sludge.

With the exception of MSWLs, the standards for each practice include numerical limits on sludge pollutant concentrations. Part 503 sets limits on pollutant concentrations for land application at two levels:

- Land Application-Low limits, which govern whether sludge can be applied to land at all; and
- more stringent Land Application-High limits which define, in part, sludge that is exempt from meeting certain record-keeping requirements.

For sludge meeting only the Land Application-Low limits, Part 503 contains pollutant loading rate limits. These determine the amount of sludge and associated pollutant content that may be applied to a particular site.

EPA did not establish pollutant-specific, numerical criteria for toxic pollutants of concern in the sludge disposed in MSWLs, because the design standards applicable to MSWLs are considered adequate to protect human health and the environment. Also, MSWL sludge is co-disposed with household waste, making precise numerical criteria infeasible. The *Solid Waste Disposal Facility Criteria* (40 CFR Part 258, Federal Register 50978, October 9, 1991) specify that POTWs using an MSWL must ensure that their sewage is non-hazardous and passes the Paint Filter Liquid Test.

The pollutant limits for sludge land application, surface disposal, and incineration constrain a POTW's choice of sludge use/disposal practice. Table 16.2 presents numerical limits for the three sludge use/disposal practices for eight MP&M pollutants. The land application pollutant limits place restrictions on concentrations of metals in sludge; the surface disposal criteria cover a subset of the metals regulated for land application. The MP&M effluent limitations guideline covers five metals and causes incidental removal of the remaining three metals regulated under the Part 503 sludge regulation. The alternative policy options would improve the quality of sewage sludge generated by POTWs receiving discharges from MP&M facilities and, as a result, would increase sludge use/disposal options for the affected POTWs.

Table 16.2: Sludge Use/Disposal Pollutant Limits

Pollutant	Application Limits		Surface Disposal Limits (mg/kg dry weight)[a]	MP&M Pollutants of Concern
	Low Limits (Low) (mg/kg dry weight)	High Limits (High) (mg/kg dry weight)		
Arsenic	75	41	73	✔
Cadmium	85	39		✔
Copper	4,300	1,500		✔
Lead	840	300		✔
Mercury	57	17		✔
Nickel	420	420	420	✔
Selenium	100	100		✔
Zinc	7,500	2,800		✔

[a] Pollutant limits for active sludge unit whose boundary is greater than 150 meters from the surface disposal site property line.

Source: Standards for the Use or Disposal of Sludge; Final Rules. 40 CFR Part 257 et al. Federal Register February 19, 1993a.

d. Reasons for not land-applying qualifying sludge

POTW characteristics including location, state regulations, and community concerns also affect use/disposal methods for sludge. The POTW Survey provided information on the percentage of sludge that qualified for beneficial use but was not beneficially used. Survey data indicate that 57 percent of qualifying sludge was not land-applied, for the following reasons:

- land application is more expensive than another method;
- land is not available for sludge application;
- the cumulative pollutant loads at the land application site used had been exceeded;
- the vector or pathogen requirements to land apply could not be met at an acceptable cost; and
- inclement weather, concern over liability, stakeholder complaints, stricter state standards, desire to diversify practices, or technical problems.

Of the 57 percent of sludge that was not land-applied, only 11 percent of qualifying sludge was otherwise beneficially used (i.e., sold in bags). Therefore, only 50 percent of the total qualifying sludge is beneficially used.[3] In addition, POTW Survey data indicate that, on average, 7.5 percent of all sludge that qualifies for surface disposal is not surface disposed.

16.2.3 Overview of Improved Sludge Quality Benefits

This section discusses potential economic productivity benefits resulting from cleaner sludge, describes the methodology used to estimate benefits to POTWs directly affected by the regulation, and presents the results of the analysis.

EPA expected that the alternative regulatory options would reduce MP&M facility discharges of eight metals with Part 503 limits. The influent pollutant reductions to the receiving POTWs translate into sludge with reduced pollutant concentrations, allowing the sludge to meet the criteria for lower-cost use/disposal methods. The reduction in pollutants will then provide many POTWs with greater flexibility in the disposal of their sludge, and for some the opportunity to use less expensive methods of sludge use/disposal. In some cases, wastewater treatment systems may be able to use the cleaner sludge in agricultural applications, generating additional agricultural productivity benefits. Numerous benefits will result from reduced contamination of sludge, including the following:

- POTWs may have less expensive options for use/disposal of sludge. Methods involving stricter criteria are generally less expensive than the alternatives. In particular, land application usually costs substantially less than incineration or landfilling. As a result, under the alternative policy options sludge from some POTWs may meet more stringent criteria for less expensive use/disposal methods.
- Some sludge currently meeting only Land Application-Low concentration limits and pollutant loading rate limits would meet the more stringent Land Application-High concentration limits. Users applying sludge meeting Land Application-High pollutant limits would be exempt from meeting pollutant loading rate limits. They would have fewer record-keeping requirements than users of sludge meeting only Land Application-Low concentration and loading rate limits.
- By land-applying sludge, POTWs may avoid costly siting negotiations for more contentious sewage sludge use or disposal practices, such as incineration.
- POTW sludge provides supplemental nitrogen, which enhances soil productivity when land-applied. Sludge applied to agricultural land, golf courses, sod farms, forests, or residential gardens is a valuable source of nitrogen fertilizer.
- Non-point source nitrogen contamination of water may be reduced if sludge is used as a substitute for chemical fertilizers on agricultural land. Compared to nitrogen in most chemical fertilizers, nitrogen in sludge is relatively insoluble in water. The release of nitrogen from sludge occurs largely through continuous microbial activity, resulting in greater plant uptake and less nitrogen runoff than from conventional chemical fertilizers.

[3] Percent of Qualifying Sludge Beneficially Used = (100% – 57%) +[(57% × 11%)/100%]=50%

- The organic matter in land-applied sludge can improve crop yields by increasing the ability of soil to retain water.

- Reduced concentrations of sludge pollutants not currently regulated may reduce human health and environmental risks. Human health risks from exposure to these unregulated sludge pollutants may occur from particulate inhalation, dermal exposure, ingestion of food grown in sludge-amended soils, ingestion of surface water containing sludge runoff, ingestion of fish from surface water containing sludge runoff, or ingestion of contaminated ground water.

- Land application of sludge satisfies an apparent public preference for this practice of sludge disposal, apart from considerations of costs and risk.

This analysis assumes that POTWs will choose the least expensive sludge use/disposal practice for which their sludge meets pollutant limits. POTWs with sludge pollutant concentrations exceeding the Land Application-High, Land Application-Low, or surface disposal pollutant limits in the baseline may be able to reduce sludge use/disposal costs after MP&M facilities have complied with the effluent limitations considered under alternative regulatory options.

As public entities, POTWs are not forced by the market to act as profit-maximizing or cost-minimizing agents, but rather are assumed to optimize their jurisdictional welfare function. POTWs take factors other than cost into consideration when determining their sludge use/disposal methods. These factors may include the desire to be perceived by the public as using sludge in an environmentally friendly way, or the desire to enhance relationships with clients by providing no-cost or low-cost fertilizer. Greater flexibility in disposal practices may therefore provide benefits beyond cost savings.

16.2.4 Sludge Use/Disposal Costs and Practices

This section summarizes the estimated cost differences of various use and disposal methods, based on the POTW Survey.

Alternative sludge use/disposal practices costs vary considerably among POTWs, based on several factors, the most important being the availability of local agricultural land or land suitable for surface disposal of sludge. Table 16.3 lists and ranks the use/disposal methods from least expensive to most expensive, according to the average qualitative ranking of each method in the POTW Survey.

Table 16.3: National Estimate of Qualitative Ranking of Use/Disposal Methods

	Mean Rankings
Least Expensive	Land Application-High
↕	Land Application-Low
	MSWL
↕	Bagged Application-High
	Surface Disposal in Unlined Unit
↕	Bagged Application-Low
	Surface Disposal in Lined Unit
↕	Incineration
Most Expensive	Hazardous Waste Landfill

Source: U.S. EPA, §308 POTW Survey.

Land Application-Low and Land Application-High were ranked as the two cheapest sewage sludge disposal options, supporting the assumption that beneficial use of sludge offers cost savings. The third least expensive option co-disposal in an MSWL costs less on average than either bagging sludge or surface disposing in an unlined unit.

EPA used the POTW Survey data as the primary source for estimating an average *difference* in costs among certain combinations of use/disposal practices (e.g., the cost savings achieved by switching from incineration to land application). Table 16.4 compares the cost savings realized by switching to sludge land application and surface disposal practices from less stringently regulated sludge use/disposal practices. While on average the estimates provided in Table 16.4 are expected to hold, the cost savings will vary for individual POTWs. POTWs whose sludge qualifies for beneficial use post-compliance but did not qualify for such use in the baseline may achieve cost savings in some, but not all, circumstances. For example, a POTW may not achieve cost savings from agricultural application due to sludge transportation costs or because there are less expensive alternatives for that particular facility. Switching from sewage sludge co-disposal in a MSWL to surface disposal offers no savings to a POTW.

Table 16.4: Cost Savings for Shifts in Sludge Use/Disposal Practices (2001$/DMT)

Switch From	Switch To:				
	Land Application[a] (High)	Land Application[a] (Low)	Sold in a Bag for Land Application	Surface Disposal on Unlined Unit	Surface Disposal on Lined Unit
Incineration	$103.82	$103.82	$95.91	$103.08	No Saving
Surface Disposal on Lined Unit	$126.39	$126.39	$71.89		
Surface Disposal on Unlined Unit	$6.44	$6.44	$0.59		
Co-disposal: MSWL	$100.44	$100.44	$69.96	No Saving	No Saving
Land Application-Low	$0.54-1.09				

[a] EPA assumes that the costs of land application to forests, public contact sites, and reclaimed land are similar to the costs of agricultural application.

Source: U.S. EPA analysis of the §308 POTW Survey data.

The cost section of the POTW Survey did not distinguish between low and high land application or low and high bagged application. Therefore, costs provided in the survey reflect the cost of both methods. To estimate the cost savings of avoiding these requirements by meeting Land Application-High limits, EPA used the compliance requirements for meeting Land Application-Low limits for bulk sludge (U.S. EPA, 1997). These cost savings provide a partial measure of the monetary benefit of improved sludge quality.

EPA estimates that the incremental record-keeping associated with the cumulative Land Application-Low limits requires two to four hours per application. Materials costs for meeting these requirements should be negligible. EPA estimated the record-keeping costs avoided from upgrading sludge quality from Land Application-Low to Land Application-High standards, using the following assumptions:

- a 40-acre site is a typical site size for land application (approximately 16 hectares) (US EPA, 1997);
- the typical application rate for land application is 7 DMT per hectare per application (US EPA, 1997); and
- labor at POTWs costs an average of $30.42 per hour (2001$), based on the §308 POTW Survey.[4]

Based on these assumptions, EPA estimated that $0.54 to $1.09 would be saved per DMT of sludge upgraded from Land Application-Low to Land Application-High.[5]

[4] See Appendix F for detail.

[5] Savings per DMT are calculated by dividing the estimated labor cost per application ($30.42 per Hour * Hours per Application) by the total amount of sludge disposed of per one application (16 Hectares * 7 DMT per hectare).

16.2.5 Quantifying Sludge Benefits

EPA estimated the number of POTWs receiving MP&M discharges and the associated quantity of sludge that would not meet Land Application-High pollutant limits, Land Application-Low pollutant limits, or surface disposal pollutant limits under both the baseline and regulatory options. EPA then assumed that, as a result of compliance with the MP&M effluent limitations guideline, a POTW meeting all pollutant limits for a less costly sludge use/disposal method would benefit from the reduced cost of that particular method. EPA estimated the reduction in sludge use/disposal costs using the steps described below:

1. Estimate total industrial baseline and post-compliance loadings of Part 503 regulated metals for each POTW with MP&M sample facility discharges;

2. Calculate the baseline and post-compliance sludge pollutant concentrations for all MP&M wastewater discharged to the POTW;

3. Compare POTW sludge pollutant concentrations with sludge pollutant limits for surface disposal and land application;

4. Estimate baseline and post-compliance sludge use/disposal practices based on the estimated pollutant concentrations in sewage sludge;

5. Identify POTWs that upgrade their sewage sludge disposal practices under the alternative policy options; calculate the economic POTW benefits by multiplying the cost savings for the shift in practices by the quantity of newly qualified sludge; adjust the estimate of benefits for the percentage of POTWs that cannot land apply sewage sludge due to transportation costs or other reasons, such as cold temperature; and

6. Estimate national benefits using MP&M sample facility weights.

a. Step 1: Estimate total industrial baseline and post-compliance loadings of Part 503 regulated metals

EPA estimated the quantities of Part 503 metals discharged to POTWs receiving wastewater from MP&M sample facilities and facilities operating in other metal discharging industries.[6] EPA used POTW Survey data to estimate the total metal loadings and percent of total loadings discharged to POTWs by MP&M facilities.

The POTW Survey provides the following information:

- number of known MP&M facilities discharging to the POTW,
- total loadings of each regulated metal received by the POTW, and
- percent of the total metal loadings attributable to MP&M industries.

[6] EPA did not include metals from residential wastewater due to lack of data. The effect on the analysis of omitting residential metal loadings is not known.

Table 16.5 summarizes this information by POTW flow volume.

Table 16.5: MP&M Contribution to Total Industrial Loadings Received by POTWs

MP&M Contribution	POTW size (million gallons per day)		
	2-10	11-50	>50
MP&M facilities	***Average number of MP&M facilities per POTW***		
small (<1 MG/year)	32.8	72.1	147.7
medium (1-6.25 MG/year)	2.5	8.0	24.5
large (>6.25 MG/year)	1.2	2.7	10.4
Chemicals	***MP&M percentage of total loadings by weight***		
Arsenic	7.4	14.0	7.0
Cadmium	16.1	23.4	12.8
Copper	18.9	21.6	10.9
Lead	13.8	19.8	10.3
Mercury	7.9	20.8	6.0
Nickel	25.1	24.4	15.8
Selenium	7.2	8.5	3.3
Zinc	20.2	16.0	8.2

Source: U.S. EPA, §308 POTW Survey.

EPA estimated total baseline metal loadings from all MP&M sources, as follows:

$$PLM_{k,i} = \frac{LMP_{small,k,i} \times AvgNumSm}{SampleSm} + \frac{LMP_{medium,k,i} \times AvgNumMed}{SampleMed} + \frac{LMP_{large,k,i} \times AvgNumLg}{SampleLg} \tag{16.1}$$

where:

$PLM_{k,i}$ = baseline loadings of pollutant *k* to POTW; from all MP&M sources (µg/year);

$LMP_{small,k,i}$ = loadings of pollutant *k* from small (< 1 MG/year) sample MP&M facilities, discharging to POTW *i* (µg/year);

AvgNumSm = the average number of small MP&M facilities discharging to POTW *i*; EPA estimated the average number of MP&M facilities of a given size (small, medium, large) that discharge to POTWs in given flow categories, based on the §308 POTW Survey (see Table 16.5);[7,8]

SampleSm = number of MP&M small (< 1 MG/year) sample facilities discharging to POTW;

$LMP_{medium,k,i}$ = loadings of pollutant *k* from medium (1-6.25 MG/year) sample MP&M facilities, discharging to POTWs (µg/year);

AvgNumMed = the average number of medium MP&M facilities discharging to POTW *i* (based on the POTW flow category (see Table 16.5));

[7] EPA classified MP&M facilities as small, medium, and large flow in the POTW Survey, based on their discharge volume.

[8] This analysis considers the following POTW flow categories: (1) from 2 MG/day to10 MG/day; (2) from 11 to 50 MG/day; and (3) greater than 50 MG/day.

SampleMed = number of MP&M medium (1-6.25 MG/year) sample facilities discharging to POTW *i*;

$LMP_{large,k,i}$ = loadings of pollutant *k* from large (>6.25 MG/year) sample MP&M facilities discharging to POTW *i* (μg/year);

AvgNumLg = the average number of large MP&M facilities discharging to POTW *i* (based on the POTW flow category (see Table 16.5)); and

SampleLg = number of MP&M large (>6.25 MG/year) sample facilities discharging to POTW *i*.

EPA estimated total baseline metal loadings from all industrial sources using data from the POTW Survey, as follows:

$$PL_{k,i} = \frac{PLM_{k,i} \cdot 100\%}{\%MP_k} \tag{16.2}$$

where:

$PL_{k,i}$ = total baseline loadings of pollutant *k* from all industrial sources to POTW *i* (μg/year),
$PLM_{k,i}$ = baseline loadings of pollutant *k* to POTW *i* from all MP&M sources (μg/year),
100% = the total reported POTW transfers of pollutant *k* from all industrial sources, and
$\%MP_k$ = the percentage of total reported POTW transfers of pollutant *k* from MP&M facilities in a given POTW flow category (see Table 16.5).

Post-compliance pollutant loadings to POTWs are calculated by subtracting the reduction in MP&M loadings due to the regulation from the estimated total baseline loadings.

b. Step 2: Calculate baseline and post-compliance sludge quality

First, for each metal with limits under the Part 503 regulation, EPA calculated POTW influent concentrations based on the pollutant loading and POTW flow rates, as follows:

$$IC_{k,i} = \frac{PL_{k,i}}{FL_i \times OD_i} \tag{16.3}$$

where:

$IC_{k,i}$ = POTW influent concentration of pollutant *k* (μg/liter) for POTW *i*;
$PL_{k,i}$ = total loading of pollutant k to POTW *i* (μg/year) ;
Fl_i = POTW *i* flow (liters/day); and
OD_i = POTW *i* operation days (365 days/year).

Second, EPA calculated sludge pollutant concentrations for each pollutant:

$$PC_{k,i} = IC_{k,i} \times TRE_k \times PF_k \times SG \tag{16.4}$$

where:

$PC_{k,i}$ = concentration of pollutant *k* in POTW *i* sludge (mg/kg or ppm),
$IC_{k,i}$ = POTW *i* influent concentration of pollutant *k* (μg/liter or ppb),
TRE_k = treatment removal efficiency for pollutant *k* (unitless),
PF_k = sludge partition factor for pollutant *k* (unitless), and
SG = sludge generation factor ((L-mg)/(μg-kg) or ppm/ppb).

The partition factor represents the fraction of the pollutant load expected to partition to sludge during wastewater treatment. This factor is chemical-specific. EPA uses a sludge generation factor of 5.96 (mg of chemical/kg sludge)/(g chemical/L of wastewater). The value of 5.96 is based on the "normal quantity of sludge produced" by a POTW with primary sedimentation/activated sludge/digestion/dewatering as reported in Wastewater Engineering (Metcalf & Eddy, 1972). The estimated sludge generation factor indicates that concentration in sludge is 5.96 ppb dry weight for every 1 ppb of pollutant removed and partitioned to sludge.

c. Step 3: Compare sludge pollutant concentrations at each POTW with limits for surface disposal and land application

EPA next compared sludge baseline and post-compliance pollutant concentrations to pollutant limits for land application and surface disposal using the following formula:

$$SE_p = 1 \ \ if \ \frac{PC_k}{CR_{k,p}} > 1 \qquad (16.5)$$

where:

SE_p = sludge exceeds concentration limits for disposal or use practice, p;
PC_k = sludge pollutant, k, concentration; and
$CR_{k,p}$ = sludge pollutant, k, criterion for disposal or use practice, p.

If *any* sludge pollutant concentration at a POTW exceeds the pollutant limit for a sludge use/disposal practice in the baseline (i.e., PC/CR >1), then EPA assumed that the POTW cannot use that sludge use/disposal practice. If, as a result of compliance with the MP&M regulation, a POTW meets all pollutant limits for a sludge use/disposal practice (i.e., PC/CR ≤ 1), that POTW is assumed to benefit from an increase in sludge use/disposal options.

d. Step 4: Estimate baseline sludge use/disposal practices at POTWs that can meet land application or surface disposal pollutant limits post-compliance

Benefits from changes in sludge use/disposal practices depend on the baseline practices employed. EPA assumes that POTWs choose the least expensive sludge use/disposal practice for which their sludge meets pollutant limits. POTWs with sludge qualifying for land application in the baseline are assumed to dispose of their sludge by land application; likewise, POTWs with sludge meeting surface disposal pollutant limits (but not land application pollutant limits) are assumed to dispose of their sludge on surface disposal sites.

EPA assumed that the mix of surface disposal practices employed by POTWs in the baseline (e.g., surface disposal in a lined unit and surface disposal in an unlined unit) matches that of national surface disposal practices as calculated from the POTW Survey (see Table 16.1).

POTW Survey data indicate that 25 percent of total sludge meeting Land Application-High standards is sold in bags and 75 percent is land-applied. None of the sludge meeting Land Application-Low standards is sold in bags. Each POTW meeting Land Application-High standards in the post-compliance scenario is assumed to sell 25 percent of its sludge in bags and to land-apply the remainder.

The POTW Survey shows that 34 percent of total surface disposed sludge is disposed of in lined units and 66 percent in unlined units. This mix of surface disposal practices may not match the actual sludge disposal surface practices of any individual POTW. In aggregate, however, the assumed surface disposal practices are consistent with actual POTW sludge surface disposal practices. Survey data also showed that, on average, 7.5 percent of all sludge that qualifies for surface disposal was not surface disposed.

POTWs generating sludge exceeding land application and surface disposal pollutant limits in the baseline are assumed to either incinerate sludge or place sludge in a MSWL. The survey indicates that 39 percent of sludge not land-applied or deposited in surface disposal sites is incinerated and 61 percent is placed in MWSLs. Each POTW exceeding surface disposal and land application limits in the baseline is assumed to incinerate 39 percent of its sludge and co-dispose of the remainder. Again, this mix of sludge use/disposal practices may not match the actual sludge disposal practices of any single POTW; in aggregate, however, the assumed distribution corresponds to actual practices.

Using the sludge disposal cost differentials from Table 16.4, EPA estimated savings for shifts into land application and surface disposal from the assumed mix of baseline use/disposal practices (see Table 16.6). As previously discussed, EPA assumed that 50 percent of sludge could not be used beneficially (land-applied or sold in bags) and disposed less expensively through agricultural application of sludge due to transportation costs, land availability, or weather constraints. The Agency did not estimate benefits for this percentage of the sludge newly qualified for land application.

e. Step 5: Calculate economic benefits for POTWs receiving wastewater from sample MP&M facilities

Table 16.6 shows the cost savings for shifts from composite baseline sludge use/disposal practices to land application or surface disposal. Reductions in sludge use/disposal costs are calculated for each POTW receiving wastewater from an MP&M facility, using the following formula:

$$SCR_i = FL_i \times \frac{S}{2200} \times CD_i \qquad (16.6)$$

where:

SCR_i = estimated sludge use/disposal cost reductions resulting from the regulation for POTW *i* (2001$);

FL_i = POTW *i* wastewater flow (million gallons/year);

S = sludge to wastewater ratio, assumed to be 1,127 lbs. (dry weight) per million gallons of water (lbs./million gallons) and divided by 2,200 to convert pounds to metric tons; and

CD_i = estimated cost differential between least costly composite baseline use/disposal method for which POTW *i* qualifies and least costly use/disposal method for which POTW *i* qualifies post-compliance (2001$/DMT).

Table 16.6: Cost Savings from Shifts in Sludge Use/Disposal Practices from Composite Baseline Disposal Practices (2001$/DMT)

Baseline POTW Mix of Sludge Use/Disposal Practices	Post-Compliance POTW Sludge Use/disposal Practice			
	Agricultural Application-High (75% of sludge meeting Land Application-High pollutant limits)	Bagged Sludge (25% of sludge meeting Land Application-High pollutant limits)	Agricultural Application-Low	Surface Disposal[a] (Meet surface pollutant limits; do not meet land application pollutant limits)
Meets Land Application-Low pollutant limits, but not Land Application-High limits	$0.54-1.09	N/A[b]	N/A	N/A
Meets surface disposal pollutant limits, but not Land Application-Low limits Assumed disposal mix: 34% lined unit 66% unlined unit	 $126.39 $6.44	 $71.89 $0.59	 $126.39 $6.44	N.A.
Does not meet land application pollutant limits or surface disposal pollutant limits Assumed disposal mix: 39% incineration, 61% co-disposal	 $103.82 $100.44	 $95.91 $69.96	 $103.82 $100.44	 $0-$103.08 N/A

[a] Surface disposal includes monofills, surface impoundments, and dedicated sites.
[b] Not applicable (i.e., there is no cost savings).

Source: U.S. EPA, §308 POTW Survey.

EPA assumed that only 50 percent of the sludge qualified for land application is beneficially used (i.e., land-applied or sold in bags). The remaining 50 percent of the sludge newly qualified for land application will be disposed of by other methods; therefore, EPA assumed that no cost savings will be associated with 50 percent of the sludge qualified for land application. To ensure that these benefits are not overstated, this analysis includes an adjustment to the estimate of national sludge use/disposal cost benefits for POTWs that may be located at some distance from agricultural sites. This adjustment does not apply to benefits from shifts into surface disposal.

f. Step 6: Estimate national sludge benefits

EPA scaled the sludge use/disposal cost reductions to the national level as follows:

$$NSCR = \sum_{i=1}^{n} (FW_i \times SCR_i) \tag{16.7}$$

where:

$NSCR$ = national estimated sludge use/disposal cost reductions resulting from the regulation (2001\$);
n = number of POTWs estimated to shift into meeting surface disposal or land application pollutant limits as a result of MP&M effluent limitations;
FW_i = facility sample weights for facility or facilities discharging to POTW i; and
SCR_i = estimated sludge use/disposal cost reductions resulting from the regulation for POTW i (2001\$).

16.3 Estimated Savings in Sludge Use/Disposal Costs

Of the POTWs receiving discharge wastewater from MP&M facilities, 1,020 POTWs exceed the Land Application-High pollutant limits and 856 exceed the Land Application-Low pollutant limits at baseline discharge levels under the alternative options considered for the final rule. This represents approximately 6 percent of the over 16,000 operating POTWs nationwide. The number of POTWs exceeding Land Application-High and Land Application-Low pollutant limits under the Proposed/NODA Option at baseline conditions is equal to 5,328 and 3,728, respectively.[9]

The final rule only regulates direct dischargers and, as a result, sewage sludge quality will not be affected by the selected option. EPA, however, did estimate savings in sludge disposal costs for the alternative options which consider both direct and indirect dischargers. EPA used the estimated sludge use/disposal cost differentials presented in Table 16.6 to calculate cost savings for the POTWs expected to upgrade their sludge disposal practices under alternative policy options. These results are presented in Table 16.7 below. The benefits are estimated at $11,319 to $22,539 (2001$) annually for both upgrade options. The Proposed/NODA Option would result in more substantial cost savings (i.e., $22.8 million (2001$)) to POTWs. However, the Proposed/NODA Option is not directly comparable to the two upgrade options due to inconsistent baselines.

[9] The total number of facilities reported for the Proposed/NODA Option analysis differs from the facility count reported for the final rule and the upgrade options (Directs + 413 to 433 Upgrade Option, Directs + All to 433 Upgrade Option). After deciding in July 2002 not to consider the NODA option as the basis for the final rule, EPA did not perform any more analyses on the NODA option -- including not updating facility counts and related analyses for the change in subcategory and discharge status classifications.

Table 16.7: National Estimate of Cost Savings from Shifts in Sludge Use/Disposal Under the Alternative Policy Options[a]

Shift	Category/Number of POTWs	Associated Sludge Quantity (DMT/Year)	Estimated Benefits (2001$)
Directs + 413 to 433 Upgrade			
Upgrade from minimum Land Application-Low limits to Land Application-High pollutant limits	15	16,548	$11,319 to $22,539
Upgrade from not meeting land application or surface disposal limits to Land Application-High pollutant limits	0	0	$0
Upgrade from not meeting land application or surface disposal limits to Land Application-Low pollutant limits	0	0	$0
Total	**15**	**16,548**	**$11,319 to $22,539**
Directs + All to 433 Upgrade			
Upgrade from minimum Land Application-Low limits to Land Application-High pollutant limits	15	16,548	$11,319 to $22,539
Upgrade from not meeting land application or surface disposal limits to Land Application-High pollutant limits	0	0	$0
Upgrade from not meeting land application or surface disposal limits to Land Application-Low pollutant limits	0	0	$0
Total	**15**	**16,548**	**$11,319 to $22,539**
Proposed/NODA Option			
Upgrade from minimum Land Application-Low limits to Land Application-High pollutant limits	45	88,389	$60,458 to $120,386
Upgrade from not meeting land application or surface disposal limits to Land Application-High pollutant limits	24	140,460	$6,725,273
Upgrade from not meeting land application or surface disposal limits to Land Application-Low pollutant limits	25	316,565	$16,009,889
Total	**93**	**545,414**	**$22,795,620 to $22,855,548**

[a] Based on the Traditional Extrapolation.

Source: U.S. EPA analysis.

16.4 Methodology Limitations

EPA used the POTW Survey to develop estimates of the cost-saving differentials for the various sludge use/disposal practices. Sludge use/disposal costs vary by POTW. The POTWs affected by the MP&M regulation may face costs that differ from those estimated. As a result, the analysis may over- or under-estimate the cost differentials.

POTW Survey data were also used to estimate metal loadings to POTWs in the baseline analysis. There are two major limitations associated with this approach:

- The baseline metal loadings from individual MP&M facilities of interest may differ from this estimate. The effect of using the §308 survey data to characterize the POTWs that receive MP&M discharges is therefore not known.

- The total share of metals coming from MP&M facilities is likely to be underestimated because lower flow MP&M facilities are not always known by the POTW. During the pretest of the MP&M POTW questionnaire, POTWs told EPA that they were not aware of many of the lower flow facilities that were discharging to them. The POTW would have to use the phone book in order to find and permit these facilities. EPA consequently considered exempting low flow facilities in the general metals and only oily wastes indirect discharge categories under some of the alternative regulatory options.

This analysis assumes that the mix of disposal practices estimated for a specific POTW may not match the actual sludge disposal practices used by that POTW. We know that the mix in the aggregate, as confirmed by the POTW Survey, is correct. The practices used in this analysis are therefore consistent with actual POTW sludge surface disposal practices. Because accurate assumptions for specific POTWs could not be made, the analysis may over- or underestimate the cost differentials.

EPA quantified, but did not monetize economic benefits from reducing interference with POTW operations for the alternative regulatory options. EPA did not estimate cost reductions that occur at POTWs with sludge inhibition problems caused by MP&M discharges. These omissions thereby underestimate the benefits of the regulation.

GLOSSARY

hazardous air pollutants (HAPs): air pollutants that are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride. MP&M pollutants include but are not limited to: chlorobenzene, dioxin,1,4-isophorone, and pyrene. (http://www.epa.gov/OCEPAterms/hterms.html)

hazardous waste landfill: an excavated or engineered site where hazardous waste is deposited and covered. (http://www.epa.gov/OCEPAterms/hterms.html)

influent concentrations: measure of a pollutant's concentration in wastewater being received by a POTW for treatment (see also: pollutant inhibition values).

interference: the obstruction of a routine treatment process of POTWs that is caused by the presence of high levels of toxics, such as metals and cyanide in wastewater discharges. These toxic pollutants kill bacteria used for microbial degradation during wastewater treatment (see: microbial degradation).

microbial degradation: the breakdown of organic molecules via biochemical reactions occurring in living microorganisms such as bacteria, algae, diatoms, plankton, and fungi. POTWs make use of microbial degradation for wastewater treatment purposes. This process is inhibited by the presence of toxics such as metals and cyanide because these pollutants kill microorganisms.

municipal solid waste landfill (MSWL): common garbage or trash generated by industries, businesses, institutions, and homes. Also known as municipal solid waste. (http://www.epa.gov/OCEPAterms/mterms.html)

pathogens: microorganisms (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals and plants. (http://www.epa.gov/OCEPAterms/pterms.html)

pollutant inhibition values: determined threshold concentration for a pollutant, which when exceeded by the pollutant's influent concentration in wastewater received for treatment will have adverse effects on POTW operations, such as inhibition of microbial degradation (see: microbial degradation).

publicly-owned treatment works (POTWs): a treatment works as defined by Section 212 of the Act, which is owned by a state or municipality. This definition includes any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. (http://www.epa.gov/owm/permits/pretreat/final99.pdf)

silviculture: management of forest land for timber. (http://www.epa.gov/OCEPAterms/sterms.html)

vector: 1. An organism, often an insect or rodent, that carries disease. 2. Plasmids, viruses, or bacteria used to transport genes into a host cell. A gene is placed in the vector; the vector then "infects" the bacterium. (http://www.epa.gov/OCEPAterms/vterms.html)

ACRONYMS

DMT: dry metric tons
HAPs: hazardous air pollutants
MSWL: municipal solid waste landfill
POTWs: publicly-owned treatment works

REFERENCES

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Chapter 17: Environmental Justice & Protection of Children

INTRODUCTION

Executive Order 12898 requires that, to the greatest extent practicable and permitted by law, each federal agency must make achieving environmental justice part of its mission. Therefore, EPA examined whether the final regulation will promote environmental justice in areas affected by MP&M discharges.

CHAPTER CONTENTS

EPA concludes that discharges from MP&M facilities regulated under the final rule do not have a disproportional environmental impact on minority populations, based on the demographic characteristics of the populations residing in the counties affected by MP&M discharges.

The final rule is not subject to Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks" (62 FR 19885, April 23, 1997), because it is based on technology performance and not on health or safety risks. However, EPA analyzed the reduction of children's health impacts associated with the MP&M regulation, and determined that reductions in the baseline lead exposure are minimal.

The following section assesses whether MP&M discharges have a disproportionally high impact on minority populations.

17.1 DEMOGRAPHIC CHARACTERISTICS OF POPULATIONS LIVING IN THE COUNTIES NEAR MP&M FACILITIES

EPA assessed whether adverse environmental, human health, or economic effects associated with MP&M facility discharges are more likely to affect minorities and low-income populations. This analysis uses data on the race, national origin, and income level of populations residing in counties traversed by reaches receiving discharges from the 32 sample MP&M facilities considered in the final rule analysis. The 32 sample facilities are located in 46 counties in 12 states. The MP&M survey was designed to provide a representative coverage of various types of MP&M facilities, but not of their geographical location. EPA is therefore able to analyze only the location characteristics of the sample facilities, and not all 43,901 MP&M dischargers.[1]

EPA compared demographic data from the 1990 Population Census for the counties traversed by sample ***MP&M reaches*** with the corresponding state level indicators (U.S. Census Bureau, 1990). EPA considered several demographic characteristics to assess the environmental justice of the final regulation, including the relative proportions of African Americans, Native Americans, and Asian or Pacific Islanders, median income, the proportion of the population below the poverty level, unemployment percentage, and the proportion of the population that are children. Table 17.1 presents the results of this analysis, which show that the demographic characteristics of MP&M counties generally reflect state averages.

EPA calculated median income for the group of counties in each state receiving MP&M discharges as a weighted average of each county's median household income.[2] County's populations are used as weights in this analysis. EPA calculated this summary variable in place of the true median household income for MP&M counties because appropriate census data are not

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[1] This estimate of MP&M facilities includes baseline closures.

[2] Average median income in MP&M counties =
Σ_i Median Income (i) × Number of Households (i)/Σ Number of Households (i), where (i) is a sample MP&M county.

available. The Agency notes that comparing this weighted average median income to the state-level median income may introduce uncertainty in the analysis.

Income data, as well as other characteristics examined to determine whether minority and/or low-income populations are subject to disproportionally high environmental impacts, show that the socioeconomic characteristics of populations residing in counties affected by MP&M discharges reflect corresponding state averages. Based on these findings, EPA expects that environmental benefits resulting from the MP&M rule will not accrue to populations disproportionally based on race or national origin and therefore will promote environmental justice.

Table 17.1: County Level Comparison of Demographic Data: Counties with Sample MP&M Facilities Versus Entire State

State	Counties	% White	% African-American	% Native Am., Eskimo, or Aleut	% Asian or Pacific Islander	Median Income	% Below Poverty Level	% Unemployed	% Children
California									
MP&M Only	3	58.64%	11.82%	0.53%	11.20%	$36,100	13.98%	7.04%	25.83%
Entire State	58	69.07%	7.39%	0.84%	9.57%	$35,798	12.51%	6.65%	26.01%
Indiana									
MP&M Only	3	95.38%	3.76%	0.23%	0.41%	$24,785	14.31%	7.42%	23.38%
Entire State	93	90.59%	7.75%	0.26%	0.66%	$28,797	10.68%	5.74%	26.29%
Kentucky									
MP&M Only	1	98.44%	0.54%	0.12%	0.74%	$34,485	7.40%	3.64%	29.38%
Entire State	120	92.06%	7.11%	0.19%	0.47%	$22,534	19.03%	7.37%	25.93%
Maryland									
MP&M Only	1	94.61%	4.47%	0.35%	0.34%	$36,019	7.50%	4.56%	26.86%
Entire State	24	71.03%	24.87%	0.30%	2.88%	$39,386	8.27%	4.30%	24.31%
Mississippi									
MP&M Only	3	56.88%	42.46%	0.09%	0.47%	$26,342	19.31%	6.93%	28.00%
Entire State	82	63.46%	35.59%	0.34%	0.49%	$20,136	25.21%	8.43%	29.04%
Missouri									
MP&M Only	1	99.45%	0.04%	0.44%	0.04%	$17,594	18.87%	4.00%	24.21%
Entire State	115	87.68%	10.69%	0.44%	0.77%	$26,362	13.34%	6.16%	25.71%
New York									
MP&M Only	2	92.64%	4.90%	0.34%	0.78%	$25,864	12.13%	10.57%	28.09%
Entire State	63	74.47%	15.90%	0.33%	3.83%	$32,965	13.03%	6.88%	23.66%
North Carolina									
MP&M Only	3	88.47%	10.71%	0.23%	0.33%	$26,189	10.75%	3.94%	24.10%
Entire State	100	75.60%	21.96%	1.25%	0.76%	$26,647	12.97%	4.79%	24.27%
Ohio									
MP&M Only	2	89.17%	9.69%	0.24%	0.74%	$28,527	11.70%	6.82%	24.76%
Entire State	89	87.81%	10.62%	0.21%	0.82%	$28,706	12.54%	6.60%	25.85%
Oklahoma									
MP&M Only	4	82.68%	8.48%	6.99%	1.06%	$26,456	13.63%	5.86%	26.20%
Entire State	77	82.26%	7.38%	8.03%	1.04%	$23,577	16.71%	6.87%	26.60%

Table 17.1: County Level Comparison of Demographic Data: Counties with Sample MP&M Facilities Versus Entire State

State	Counties	% White	% African-American	% Native Am., Eskimo, or Aleut	% Asian or Pacific Islander	Median Income	% Below Poverty Level	% Unemployed	% Children
Pennsylvania									
MP&M Only	22	92.89%	6.12%	0.12%	0.64%	$27,851	11.56%	6.46%	22.88%
Entire State	68	88.57%	9.15%	0.13%	1.14%	$29,069	11.13%	5.97%	23.54%
Washington									
MP&M Only	1	84.94%	4.97%	1.18%	7.90%	$36,179	7.96%	4.15%	22.56%
Entire State	40	88.64%	3.03%	1.71%	4.34%	$31,183	10.92%	5.72%	25.86%

Source: U.S. EPA analysis of 1990 Census Data (U.S. Bureau of Census 1990).

17.2 Protection of Children from Environmental Health and Safety Risks

EPA assessed whether the final regulation will benefit children, including reducing health risk from exposure to MP&M pollutants from consumption of contaminated fish tissue and drinking water and improving recreational opportunities. EPA was able to quantify only one category of benefits specific to children: avoided health damages to pre-school age children from reduced exposure to lead. This analysis considered several measures of children's health benefits associated with lead exposure for children up to age six. Avoided neurological and cognitive damages were expressed as changes in three metrics: (1) overall IQ levels; (2) the incidence of low IQ scores (<70); and (3) the incidence of blood lead levels above 20 mg/dL. EPA also assessed changes in the incidence of neonatal mortality from reduced maternal exposure to lead. EPA's methodology for assessing lead-related benefits to children is presented in Chapter 14 of this report.

The Ohio case study analysis showed that the final rule is expected to yield $422,000 (2001$) in annual benefits to children in the state of Ohio from reduced neurological and cognitive damages and reduced incidence of neonatal mortality. On the other hand, the national-level analysis shows that benefits to children from reduced lead discharges are negligible nationwide. As noted in Chapter 18, different findings from these two analyses are likely to be due to insufficient data and a more simplistic approach used in the national-level analysis.

Children over age seven are also likely to benefit from reduced neurological and cognitive damages from reduced exposure to lead. Giedd et al. (1999) studied brain development among 10 to 18 year-old children and found substantial growth in brain development, mainly in the early teenage years. This research suggests that older children may be hypersensitive to lead exposure, as are children aged 0 to 7.

Additional benefits to children from reduced exposure to lead not quantified in this analysis may include prevention of the following adverse health effects: slowed or delayed growth, delinquent and anti-social behavior, metabolic effects, impaired heme synthesis, anemia, impaired hearing, and cancer (see Chapter 14 of this report for details).

Glossary

MP&M reach: a reach to which an MP&M facility discharges.

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